People, Politics and Power Stations

Electric Power Generation in New Zealand 1880—1998

Edited by John E. Martin

Electricity has helped to shape the twentieth century. The history of electricity generation in New Zealand, told here through the story of government construction of the country's power stations, tells us much about our own past.

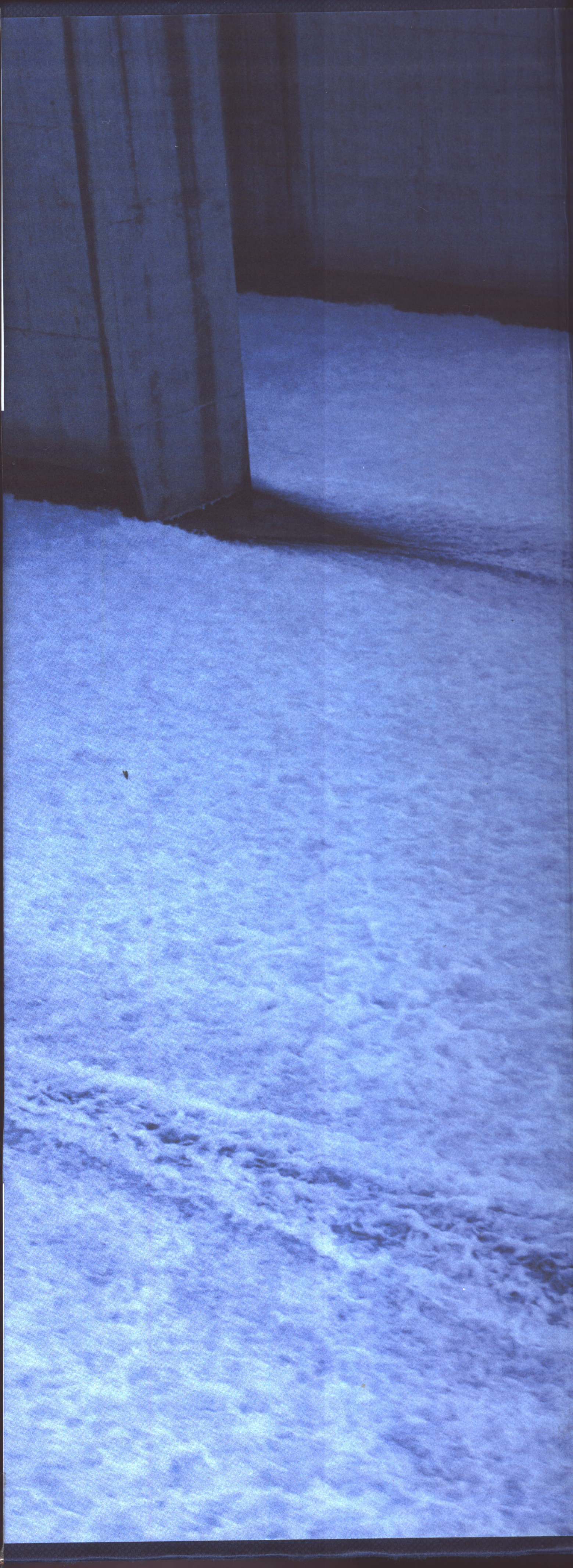
People, Politics and Power Stations begins with the early days of power generation at Reefton, and follows the rapidly expanding schemes from the 1920s, as electric power spread all over the country. The massive developments of the Waikato, Waitaki and Clutha Rivers, and the establishment of geothermal and thermal stations, are histories in their own right. All these projects are documented, and planning, engineering and environmental issues are fully covered.

Illustrated with more than 200 photographs and line drawings, this careful account reveals the profound impact of technological innovation and enterprise in New Zealand. It pays tribute also to this country's professional engineers and construction workers.

This new edition makes available again a publication that has been in strong demand since it was first published in 1991.

It documents the end of a significant phase in government electricity generation – one in which the country's largest state-owned enterprise, ECNZ, has played a major role.

People, Politics and Power Stations offers a history of the changes leading eventually to the transformation of the electricity industry and the break-up of ECNZ. This last wave of industry reforms will flow on to the next century, bringing new dimensions and different challenges to New Zealand's electricity sector.



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ELECTRIC POWER GENERATION IN NEW ZEALAND 1880–1998

Edited by
John E. Martin
Historical Branch
Department of Internal Affairs

ELECTRICITY CORPORATION OF NEW ZEALAND
AND
HISTORICAL BRANCH, DEPARTMENT OF INTERNAL AFFAIRS

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PREFACE

The history of planning for electricity supply and the construction of power stations by the government in New Zealand tells us much about our past and reflects the kind of society that has evolved in this country. It demonstrates the profound impact of technological innovation and enterprise in a country as far away as it could be from the centres of such developments in Europe and the United States. This history documents the crucial role played by New Zealand's engineers in developing solutions to the complex issues of electricity generation. It also tells the story of the last decade, during which the engineering focus was subordinated to the need to improve the efficiency of the generating system and state generation became enmeshed in the reform of the electricity industry.

The electricity-generating industry is a vital part of the country's economy. Investment in generating plant has from the beginning been a crucial aspect of the government's role in providing an infrastructure. It comprises a substantial proportion of national investment and makes a central contribution to economic development. This in itself has assured the industry of a key role in the economy and in political and philosophical debates about the kind of society we want. This history is integral to the story of New Zealand's development as a whole.

The unfolding story of generation in this country mirrors the development of our society, politics and economy. We see how fundamental electricity has been to social patterns and transformations of our way of life: the relationship between urban and rural New Zealand, changing patterns of domestic work, leisure and recreation, changing forms of transport, and the shaping of industry. Since the 1950s, it has also been at the heart of the way New Zealanders view their relationship with the natural environment and the issue of energy conservation.

This history also tells us much about the key role played by central government and its departments, and the way that this unfolded: the complex planning problems posed by the rising demand for electricity, shifts in policy with successive governments, inter-departmental conflict and rivalry, and the sheer achievement of designing, building and operating what have included this country's largest engineering projects.

We should also not neglect the vital contributions of key people. Without their vision and imagination, enterprise and innovation, and energy and drive, we would not have the system we enjoy today, a system which performs efficiently and provides that elusive commodity which we all take so much for granted. This vital contribution has to be acknowledged and this story told.

This book had its origins in work commissioned by the Electricity Division, Ministry of Energy, in 1985 as part of preparations for the centennial year of electricity in New Zealand in 1988. The work was not published at that time and remained incomplete, and in 1990 the Historical Branch of the Department of Internal Affairs was given the task of preparing a final text for publication. John E. Martin, a Senior Historian in the Branch, was largely responsible for this work, which involved the revision, editing and checking of the existing draft; further research and the writing of additional chapters and sections; and the selection of illustrations. Peter O'Connor and Mary Ronnie, who in the initial phase of the project researched and wrote the first draft, are not responsible for the text in its published form.

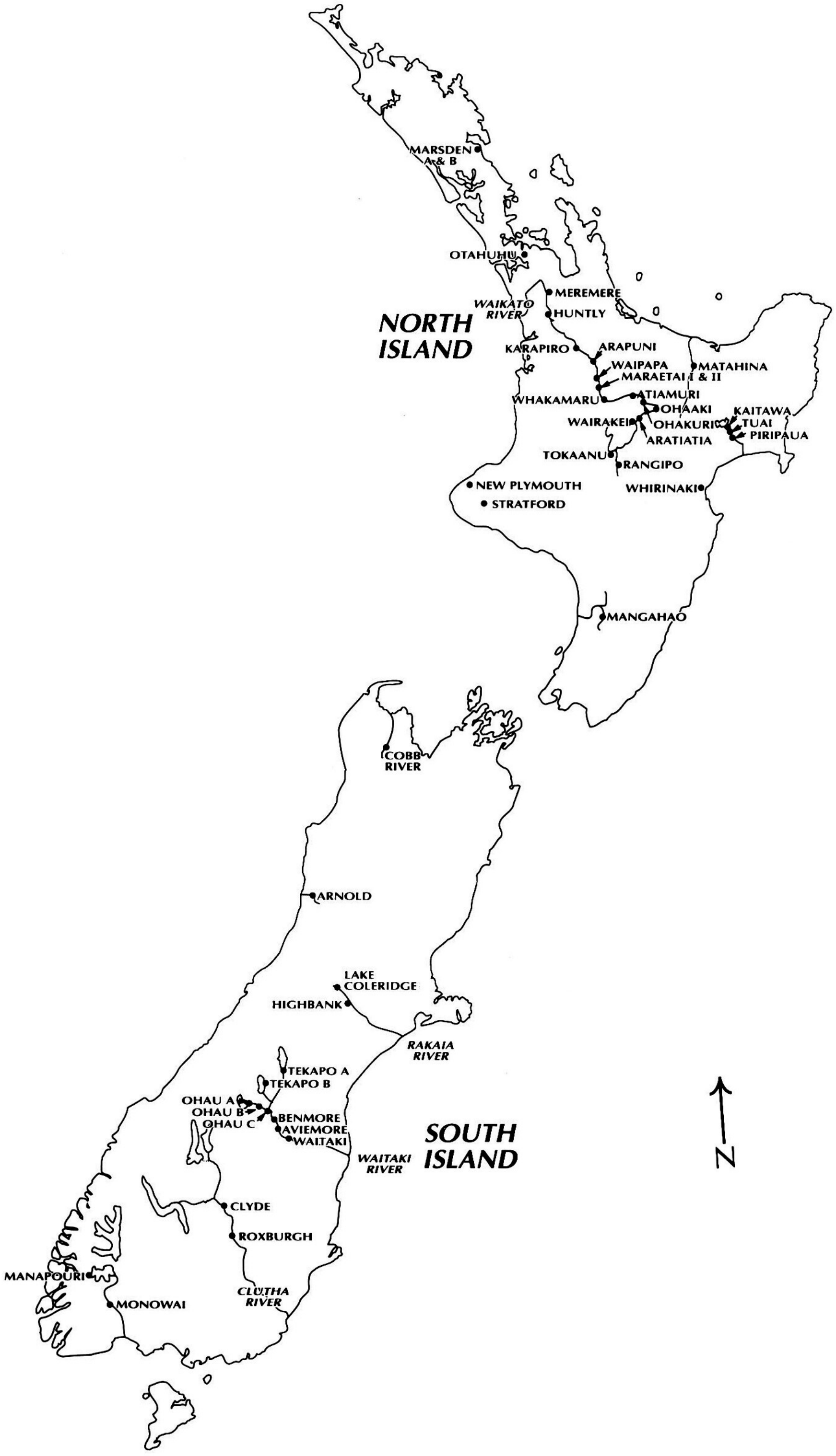
I would like to thank the following people who gave considerable assistance in the preparation of this book: Dr Rob Aspden (Principal Investigations Engineer, Projects Services Branch, Works Consultancy Services Ltd), Stewart Astwood (Senior Technical Adviser, ECNZ Production), Philip Blakeley (former General Manager of the Electricity Department), Ian Crabtree (former Principal Supply Engineer, ECNZ), Doug Dell (former National Manager, EMEC, ECNZ), Kevin McCool (former General Manager of the Electricity Division, Ministry of Energy), Robin McKenzie (former Principal Generation Engineer, ECNZ), Gil Natusch (former Principal Investigating Engineer, Ministry of Works and Development) and Bob Offe (former Chief Development Engineer, Power Division, Ministry of Works and Development). I would also like to thank for their assistance Jock Phillips (Chief Historian in the Historical Branch), Juliet Hensley (Corporate Relations Manager, ECNZ), Erica Tenquist and the librarians at ECNZ, and in particular Diana Maunder (Library Manager). Jim McRoberts, former Inspecting Superintendent (Operations), ECNZ, assisted greatly with the preparation of the first edition, giving a great deal of his time, and was always helpful and available.

In 1998 ECNZ decided that it wanted to republish *People, Politics and Power Stations* in an updated form that took account of the momentous changes of the last decade. The Historical Branch, Department of Internal Affairs, was commissioned for this work and John E. Martin researched and wrote the new material. A few minor corrections were made to the first edition, and a small number of photographs that were no longer available were replaced for this edition.

For the second, revised edition I would like to thank Lynn McClelland (Corporate Relations Manager) in particular for her role in managing the project, for her judicious eye and her readiness to respond to requests despite having more pressing business. Diana Day (photographic librarian) greatly assisted in retrieving and obtaining photographs. I am grateful to the ECNZ readers of the additional draft chapters for their comments and encouragement both in writing and by telephone. They were Dave Frow (Chief Executive), Jim Ryniker (ex-Chief Financial Officer and ex-Deputy Chief Executive), Geraldine Baumann (General Counsel), John Boshier (General Manager, Strategic Development), Kieran Devine (General Manager, Generation) and Brian Cox (New Generation Investigations Manager). Dr Roderick Deane, ex-Chief Executive of ECNZ and Chief Executive and Managing Director of Telecom, also read the draft and made numerous helpful comments. I would also like to thank Dr Roderick Deane and Bob Thomson (Chief Executive of Trans Power) for allowing me to interview them. A number of other people in ECNZ have been very helpful with aspects of the additional chapters: Robin Brasell (Environmental Adviser), Dennis Dawson (Business Manager), Margaret France (Policy Analyst), Mark France (Business Development Manager), Giuseppe (Jo) Grilli (Technical Manager, Northern Generation Group), Robert Gordon (Strategic Adviser), Martin Holden (ex-Financial Accounting Manager), Russell Howie (Environmental Manager), Sunil de Silva (Planning and Reporting Manager), and John Stewart (Projects Manager, Northern Generation Group). Robert Riley (Trading Manager, First Electric) and Ben Otang of the Ministry of Commerce also assisted.

Claudia Orange (Acting Chief Historian, Historical Branch) assisted in commissioning the revised edition, while Bridget Williams and Julia Marshall of Bridget Williams Books prepared it for publication. Both the original and revised texts were meticulously copy-edited by David Green of the Historical Branch.

John E. Martin



Electricity Corporation Power Stations, 1990

MARSDEN A & B
OTAHUHU
MEREMERE
WAIKATO RIVER
HUNTLY
NORTH ISLAND
KARAPIRO
ARAPUNI
WAIPAPA
MARAETAI
MATAHINA I & II
WHAKAMARU
ATIAMURI
OHAAKI
WAIRAKEI
OHAKURI
ARATIATIA
KAITAWA
TUAI
PIRIPAUA
TOKAANU
RANGIPO
NEW PLYMOUTH
STRATFORD
WHIRINAKI
MANGAHAO
COBB RIVER
ARNOLD
LAKE COLERIDGE
HIGHBANK
RAKAIA RIVER
TEKAPO A
TEKAPO B
OHAU A
OHAU B
OHAU C
BENMORE
AVIEMORE
WAITAKI
SOUTH ISLAND
WAITAKI RIVER
N
CLYDE
ROXBURGH
MANAPOURI
MONOWAI
CLUTHA RIVER

PART ONE

Beginnings 1880–1917

CHAPTER ONE

Power Pioneers

THROUGHOUT THE INDUSTRIAL WORLD, electricity has supplanted steam as the 'prime mover' of the twentieth century. It has also replaced gas as a source of light, and competes with gas, oil and coal as a source of heat. As the twentieth century progressed, electricity became seen as a key symbol of modernity and of a society in which all had access to the convenience and comforts of reliable and safe lighting at the touch of a switch, and to instant clean energy for cooking and heating the house, and for powering the increasing number of household appliances. The ready availability of electricity has led to the development of electronics and telecommunications, and the increased miniaturisation that has produced the familiar microchip and other wonders of computer technology.

There are many advantages in electricity as a form of energy, but probably two are most crucial. It can be easily transmitted over distances to be used where needed, instantly and in the quantity required; and it is easily converted into the three major forms of energy: heat, light and motive power. This flexibility and versatility lies at the heart of electricity's ability to revolutionise the way we produce things and the way we live. Production both in factories and on the land was radically altered by the application of electricity. Domestic living arrangements and tasks were transformed. New forms of entertainment and culture became possible, while communications were revolutionised by electrical technology.

It was not until 1831, when Michael Faraday rotated a copper disc between the poles of a powerful magnet, that the mechanical generation of electricity was understood. He found that a current was generated if wires were connected to the edge and centre of the disc. Up to that time electricity had been produced by storage battery. Faraday's simple generator demonstrated how the kinetic energy of motion could be transformed into electrical energy with remarkable efficiency (close to 100 per cent), and this opened the way in principle for the creation of ever-greater sources of electrical power, and also, by the same principle in reverse, the application of electrical energy to drive electrical motors.

Dynamos were developed and available from the mid-1860s. Various improvements were made in winding the armature and by the use of electromagnets instead of permanent magnets. In 1873 the first electric motor was developed. In 1878 Thomas Edison developed the 'bipolar' dynamo, and in 1881 C. F. Brush constructed the first 'compound wound' generator. By now dynamos were able to generate electricity cheaply enough to be commercially viable.

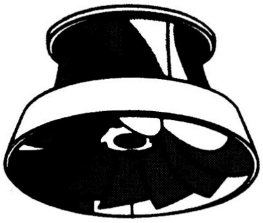
Initially, efforts in the practical application of electricity went into the development of lighting. By 1876 the electric arc light had been developed. In 1878 Brush inaugurated the commercial use of arc lights, and by the end of the decade both Edison in the United States of America and Joseph Swan in England were working on an incandescent lamp, which was more suitable for indoor use. Incandescent lighting was demonstrated at 'Electric Exhibitions' in Paris in 1881 and at London's Crystal Palace in 1882. In September 1882 Edison's Pearl Street plant began the first 'central station' public supply of electricity by illuminating a square mile of the financial district of downtown New York. Restaurants, shops and offices were lit. This station used steam engines to drive up to six of Edison's own 'Jumbo' generators, which before long lit more than 8,000 lights.

By the 1880s the modern alternating current (AC) induction motor had been developed and the practicalities of AC transmission of electricity were being tackled. AC current could have its voltage increased or decreased by means of transformers, and a high voltage with little current could be transmitted over much greater distances than could direct current (DC). The voltage could then be reduced close to where the electricity was required. This made possible a central generating station serving a number of consumers at a considerable distance through transmission lines.

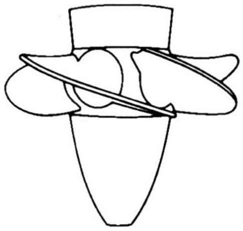
The first patent for an AC distribution system was granted in 1882. In 1886 William Stanley in the United States demonstrated the practicality of 'central station' AC transmission and transforming of voltage, and this system was soon widely adopted by Westinghouse. This led to the so-called 'battle of the systems', in which Edison's earlier low-voltage DC system, with its transmission handicap, competed with the high-voltage single-phase AC, which lacked a practical motor. The DC system was most efficient where demand was restricted to lighting and when there were high variations in load. The emerging AC system was associated with a broadening of load to industrial, motive and electrochemical uses.

In 1888 Tesla solved the AC motor problem with the first 'two-phase' motor, and in 1891 the first long-distance (110 miles) 'three-phase' generation and transmission of AC current (at 30 kV) was demonstrated at the electrical exhibition at Frankfurt in Germany. The battle was won by AC, but because of the considerable existing investment DC remained important in densely populated urban areas, particularly for electric traction. By the 1890s much generation was of AC current, and by 1900 the three-phase system and the induction motor had become the norm. The development in the 1890s of 'couplers', such as rotary converters, which changed AC current into DC and vice versa, allowed the two systems to coexist. The technology of electricity had now evolved from the era of the electric light to one of single integrated transmission systems providing both incandescent and arc lighting and both DC and AC motive power. The Westinghouse display at the Chicago Exposition of 1893 exemplified these advances.

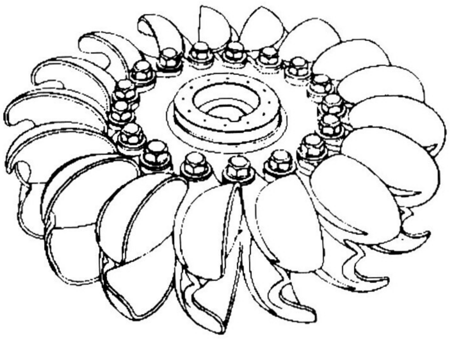
Most of the turbines installed in state hydro-electric schemes in New Zealand are of the vertical shaft Francis type. Exceptions are the earlier Coleridge station with horizontal Francis turbines, and the Mangahao and Tuai stations which were equipped with horizontal Pelton turbines; Arnold, Karapiro, Tekapo A and Waipapa stations, which have variable pitch Kaplan turbines; and Waitaki, where two of the seven units are of the fixed-blade propeller type.



FRANCIS TURBINE



KAPLAN TURBINE



PELTON TURBINE

The development of the water turbine was another crucial technological breakthrough. In 1832 a 'reaction' (or pressure) turbine had been developed in France by Fourneyron. This was a radial outflow type that was most suited to a low 'head' of water with a steady flow. By 1838 the inward-flow reaction turbine had been developed in the United States, and in 1849 James B. Francis designed a much improved version that became universally known as the Francis turbine. This was suited to a wide range of heads.

Experiments in the utilisation of high heads of water were also carried out. A modified form of the ancient water-wheel, in which buckets around the wheel's circumference were struck by a high-velocity jet of water, was developed. This was known as the 'hurdy gurdy'. This type of 'impulse' turbine was perfected on the Californian goldfields by Lester Pelton from 1860, and known from then on as the Pelton wheel. It was simple, cheap, had an efficiency of about 80 per cent (which was good at that time) and worked well with heads of more than 100 feet.

The first hydro-electric scheme began operating in Switzerland at the same time as Edison lit a small part of New York. Soon other schemes were commissioned in the United States and France. In these three countries, with massive water resources and suitable topography, hydro-electric power soon became of great importance for industries and mining, but because the electricity could not be transmitted for more than a few miles, it had to be used close to the water resource, often for the on-site extraction and exploitation of mineral resources.

The Niagara Falls hydro-electric power scheme, built by the Niagara Falls Power Company and finished in 1895, was a landmark in harnessing the power of water and in demonstrating both the large central station principle and the distribution of AC current over a wide area. Working with a head of close to 140 feet, two powerhouses generated a total of 70,000 hp using twenty turbines. Three-phase AC electricity was transmitted to Buffalo, some twenty miles away. From 1907 the development of suspension insulators allowed the transmission of AC voltages higher than 30–40 kV, and opened up the long-distance transmission of electricity from large plants.

Water has always been a key source of power in New Zealand. The country's relatively high rainfall, well spread throughout the year, and its topography and the scattered nature of settlement all lent themselves to the use of water for power generation. The Pelton wheel was frequently used in early hydro-electric schemes in New Zealand, particularly in mining areas in the South Island where large heads were often available. This had been patented in 1880 and first became available in New Zealand from 1884 when A. and G. Price, a Thames engineering firm heavily involved in mining equipment, obtained the rights. However, the Francis turbine is usually used in New Zealand today.

Electric lighting

The first use of electricity in New Zealand was in 1861 for the private electric telegraph line between Dunedin and Port Chalmers. The first government lines, built by provincial councils, linked Christchurch to Lyttelton in 1863, and Invercargill to Bluff in the following year. The Electric Telegraph Act of 1865 established a central government monopoly over the transmission of messages, and provided for state construction, maintenance and regulation of telegraphic communications. This legislation became the basis for later governmental regulation of the burgeoning electricity industry. Provincial lines were soon acquired by the central government and the entire country was rapidly linked. A telegraph cable across Cook Strait was laid in 1866.

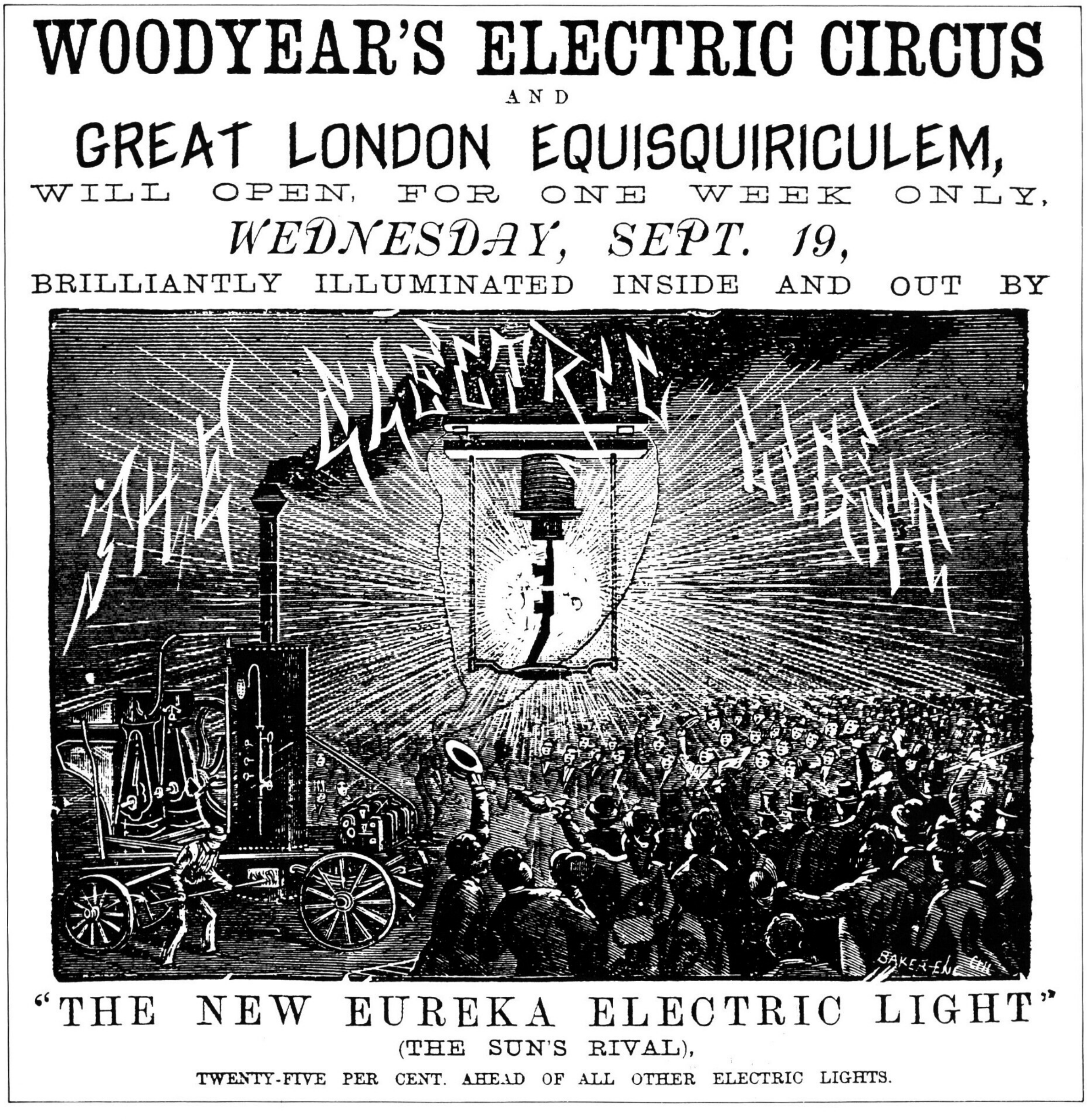
As in other countries, the first substantial use of electricity in New Zealand was for lighting.[1] The public followed developments overseas with interest, but general acceptance of electricity was slow to develop because gas was already well established for street lighting and so vested interests were threatened. The first examples of electric lighting were largely viewed as curiosities. In April 1879 a jeweller's window in Wellington's Lambton Quay was lit. An evening football match at the Basin Reserve in the same city in June that year was not very successful, as the lighting covered only half the pitch, and flickered and intermittently went out; the game had to be cut short when the engine overheated. The well-known Professor Bickerton of Canterbury University College began his public career as an exponent of electricity with a successful demonstration of electric light at the Christchurch Exhibition in July 1880. Coles Circus lit its performance ring, which was described as 'brilliantly illuminated by electric light . . . as light as day', by the end of that year.[2] Electricity became an integral part of the exhibitions that were a common and popular spectacle in the late nineteenth century.

The early 1880s was a period of 'firsts' in electricity use as the development of the technology quickly reached a commercial stage. At this time there was great interest internationally in this new phenomenon, which culminated in wild speculation in electrical company shares in Britain in 1882. In late 1881 the Union Steam Ship Company launched the SS *Manapouri*, one of the first merchant ships to be fitted throughout with incandescent lighting, which was powered by a Siemens dynamo. In July 1882 the factory of Roslyn Mills in Dunedin was lit. This was the first practical use of electricity in New Zealand beyond demonstrations and displays. By February 1883 Kaiapoi Woollen Mills had followed suit.

It has often been suggested that the first private house to be lit by electricity was that belonging to Moss Davis, at 29 Princes Street, Auckland, in November 1882, but no direct evidence has been found for this claim. In the same month, it was asserted that a resident of east Invercargill had made 'the first practical application of electric light for household purposes'.[3] In May 1883 newspapers claimed the same distinction for Dr Charles Lemon, Superintendent of Telegraphs in Wellington, whose gas-engine-driven Siemens dynamo for his twenty-candle-power Swan lamps made sufficient noise to irritate his neighbours.[4] Lemon clearly had a strong interest in publicising and extending the use of electricity, which he saw as the power source of the future.

He had also been instrumental in introducing the telephone and, in 1880, ensuring a government monopoly over the service.

At this time Dr Lemon was also engaged in the very public business of lighting Parliament Buildings. This had been discussed in the first session of 1882 when T. Kelly, MP for New Plymouth, had proposed that enquiries be made. Kelly enthused about news gathered from around the world of the power of 'waterfalls' being converted to electrical energy and carried by copper wire to centres of population. By June 1883 a 16 hp gas engine had been installed, Parliament was wired, and 300 Swan lamps had been hung at a



WOODYEAR'S ELECTRIC CIRCUS

AND

GREAT LONDON EQUISQUIRICULEM,

WILL OPEN, FOR ONE WEEK ONLY,

WEDNESDAY, SEPT. 19,

BRILLIANTLY ILLUMINATED INSIDE AND OUT BY

"THE NEW EUREKA ELECTRIC LIGHT"

(THE SUN'S RIVAL),

TWENTY-FIVE PER CENT. AHEAD OF ALL OTHER ELECTRIC LIGHTS.

Electricity was a big drawcard in the 1880s, and was soon adopted by travelling circuses such as Coles, and Woodyear's 'Electric Circus'. Safe, steady and brilliant lighting contributed greatly to the spectacle of the circus. The visits to Reefton of Woodyear's circus in 1884 and 1885 may well have been a factor in the town's early decision to provide public electric lighting.

NZ Herald, 17 September 1883

considerable cost.[5] Members grumbled about loud bangs from the engine and fluctuations in the brightness of the light, but Dr Lemon remained pleased with the result.

Before long electricity was being considered for municipal street lighting, and battle was joined with the vested interests of the gas companies. Those advocating electricity found this difficult at a time when gas lighting was being improved considerably and made cheaper. Often city and borough councillors associated with the local gas company opposed the introduction of electricity.

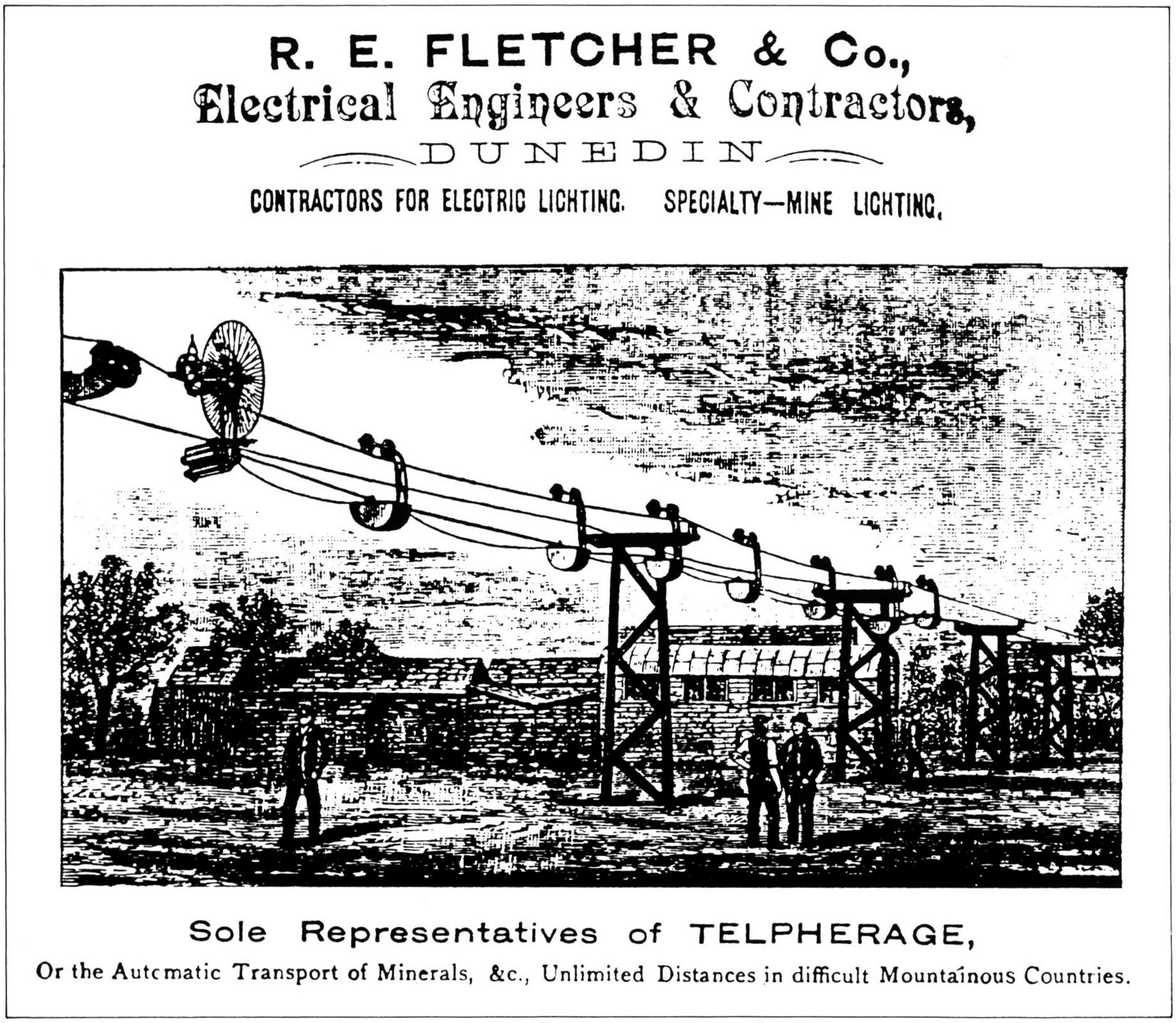
Various electrical companies now entered the field. Sir Julius Vogel was involved in establishing the Australasian Electric Light, Power and Storage Company, which in 1882 became agent for the Anglo-American Brush Electric Light Corporation, a company that was to supply many dynamos and electric motors for use here. Vogel also encouraged the formation of the subsidiary New Zealand Electric Light Company, which was particularly active, if rather unsuccessful in producing workable systems.

One of the more successful firms was Miles and Company of Christchurch, agents for the Gulcher Electric Light and Power Company of England. The company failed to persuade the Dunedin City Council to let it light the city in 1883, which was unsurprising since the council operated its own gasworks and referred the application to its Gas Committee! But they did gain the concession to light Christchurch's streets, and in 1883 successfully demonstrated lighting at the railway yards and the Kaiapoi Woollen Mills and later at the Lyttelton wharves, where a 'Gulcher' system was installed.

The New Zealand Electric Light Company had previously won a contract to light Lyttelton wharves with sixteen 2,000-candle-power lights supplied by a Brush generator. Walter Prince arrived in Lyttelton on 22 February 1883 to install the equipment, having travelled on the electrically lit SS *Manapouri*. But this plant failed to give satisfaction, even after months of trials, because of inadequate insulation, a problem that would plague Prince. The New Zealand Electric Light Company, which had purchased the New Zealand rights of Vogel's Australasian Electric Light Company, had some limited success in Dunedin, however, with Watson's Hotel (which was illuminated brightly enough for photographs to be taken in the hall) and the *Otago Daily Times* building. The company had lights and electrical equipment on show at the Christchurch Industrial Exhibition over the summer of 1883-84, but these proved unreliable. Other companies throughout the country were engaged in lighting single buildings in this way, while centres as far apart as Auckland and Cromwell were investigating the cost of street lighting, but without immediate results.

Walter Prince was a key figure involved in many early electrical developments in New Zealand, including those at Bullendale and Reefton. He was a clever and flamboyant seller of the idea of electricity, and backed this up with considerable technical expertise at a time when electrical installations were very experimental indeed, particularly as technical assistance was months away on the other side of the world. Prince was, in practice, much more successful at selling ideas than in carrying proposals to a practical conclusion. He arrived in this country in 1882 as an agent for Vogel's Australasian Electric Light, Power and Storage Company and its subsidiary, the New Zealand Electric Light Company, and acted as their salesman and installation electrician. He spent much of the next six years touring the country giving lectures and trying to persuade investors in mining, industry, towns and cities to purchase electrical systems. When R. E. Fletcher took over the New Zealand company, Prince worked for him, demonstrating electricity at the 1885 Industrial Exhibition in Wellington and installing the equipment at Bullendale in 1885-86. He then persuaded people in Reefton to set up a company that constructed and ran New Zealand's first electrical system selling power to the public, which became operational in 1888. During this period he was also involved in unsuccessful lighting trials for the Lyttelton (1883) and Auckland (1885) wharves, and in public lighting in Wellington in 1887. After Reefton, where he forfeited his shares in the company because of problems with the system, Prince tried his luck on the Thames goldfields and disappeared from public view.

The Electric Telegraph Act had been consolidated in 1875, and was now incorporated in the Electric Lines Act 1884, which extended the coverage of the legislation to the electric lighting of public places and to telephones.[6] Concern was expressed that companies were being formed to exploit the interest in electric lighting, such as the Brush Company, which had plans for Dunedin. The Act of 1884 was probably influenced by the



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Electrical Engineers & Contractors,
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Sole Representatives of TELPHERAGE,
Or the Automatic Transport of Minerals, &c., Unlimited Distances in difficult Mountainous Countries.

R. E. Fletcher of Dunedin was a key pioneer supplier and installer of electrical equipment. He installed the lighting in the Mosgiel Woollen Mills in 1885, exhibited at the New Zealand Industrial Exhibition that year, and supplied the machinery for the Bullendale and Reefton plants, the Sandhills electric dredge and, later, the first government plant, at Okere Falls, near Rotorua.

Mills, Dick and Co., *Otago Directory*, 1886

British Electric Lighting Act 1882, which placed considerable restrictions on the development of electricity by private enterprise. The Electric Lines Act provided for the appointment of a Superintendent of Electric Lines to ensure proper quality and care of installations, and empowered the Governor to make regulations for the protection of the public from the dangers of electricity. Another concern that was to persist was the prevention of interference caused by induced currents between adjacent telegraph or telephone lines and electric lines. However, the provision with the most important long-term consequences was the prohibition of the erection by private individuals or companies of lines for public supply without special legislation. This introduced the crucial principle, subsequently enlarged, of government control over this new source of power.

Increasingly, buildings were lit by private generating plants. R. E. Fletcher of Dunedin was a pioneer supplier of electrical equipment. He was the representative in this country of the Australasian Electric Light Company, and probably took over its subsidiary, the New Zealand Electric Light Company. Fletcher installed lights in the Mosgiel Woollen Mills in 1885.

The New Zealand Industrial Exhibition, held in Wellington in 1885, provided a showcase for Walter Prince, who exhibited on behalf of R. E. Fletcher.[7] Prince had originally proposed that the entire exhibition be lit by electricity, but this suggestion was not carried out. Instead, he erected a cluster of three 1,000-candle-power arc lights atop a 100-foot-high iron mast in the centre of the internal courtyard of the exhibition building. One of A. and G. Price's Pelton wheels, driven by water from the water mains, was connected to a dynamo lighting some 50 Swan incandescent lamps of twenty candle-power each, which were arranged around Prince's machinery.

Prince also appeared in Auckland in 1885, acting both for Fletcher and as the Union Steam Ship Company's Superintendent Electrician. He was there to set up trials for lighting Queen Street wharf, and to provide a searchlight to improve the defences of Auckland Harbour against a feared Russian invasion. Prince's wharf-lighting demonstrations were no more successful than those at Lyttelton had been. Fletcher then sent extra equipment and orchestrated a successful demonstration in January 1886, but the harbour board decided to use gas instead.

Bullendale

By the mid-1880s the first significant generation and transmission of electric power in New Zealand for purposes other than lighting had been achieved at Bullendale in Central Otago.[8] This was also the first major hydro-electric generation of power in the country, and possibly the first electrically powered stamping battery in the world. It was no accident that this development occurred in a gold mine and in isolated Central Otago. Such quartz mines required a great deal of motive power and were often in areas that were remote from sources of fuel for steam power but had plentiful water, which was already used extensively for sluicing and driving water-wheels. At the time gold mining was one of New Zealand's most important industries, and required considerable capital and heavy machinery, particularly when the gold had to be extracted from quartz by crushing in stamping batteries. This industry attracted innovative entrepreneurs who were likely to be willing to risk using advanced technologies such as electrical power. Gold mining was responsible for the early development of hydro-electric schemes at Bullendale, Reefton, in the Thames area and for gold dredging on South Island rivers.

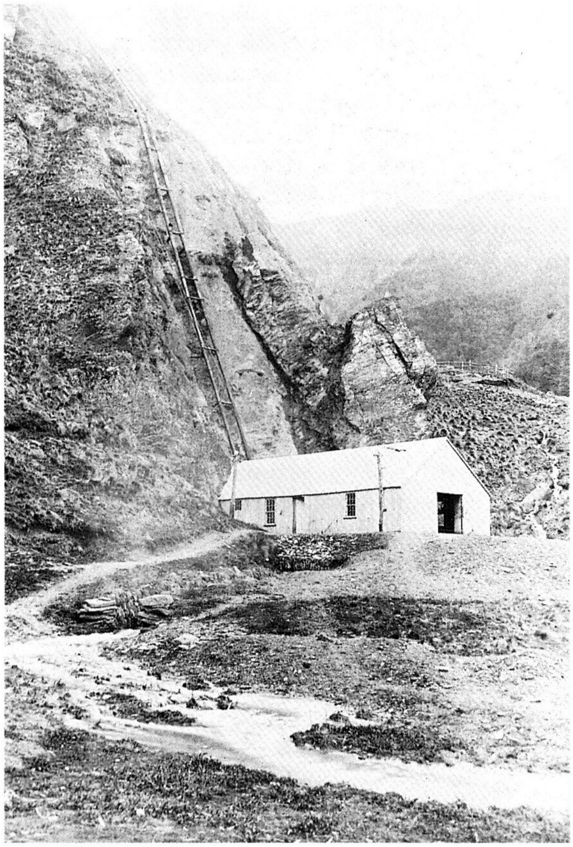
Bullendale: Constructed 1885–86. Head 185 feet. Water was carried by an open race to the top of a bluff, and then by a tapering wrought-iron pipeline down to the powerhouse containing two 50 hp Pelton wheels 6 feet in diameter. The Pelton wheels drove DC Brush Arc dynamos, which were amongst the largest then made. Lines made of No. 8 copper wire carried the power over a ridge to the 30-stamper battery nearly two miles away, where a large, specially constructed Brush Victoria motor was installed.

Bullendale, near Queenstown, was in the late nineteenth century a considerable township. More than 200 men were employed in the mine, and there were two butcher's shops and a school, bakery, hotel, hall, billiard room, library and post office. The notable quartz reefs of Bullendale, in the right branch of Skippers Creek, had been discovered in 1863. In 1874, when the Phoenix Quartz Mining Company was floated, the Bullen brothers took over control of the mine. However, they had continuing problems with the water supply that had driven the stamping battery for twenty years. The supply was adequate only for four months of the year, during which a 30 hp Leffell turbine was used to drive the battery of twenty stampers. Other miners had prior rights over the water, which was insufficient in summer and froze in winter. Steam power was not a practical alternative because of the difficulty of getting coal to the site, although in 1885 a 14 hp steam engine was brought in to drive the stampers while electric power was awaited.

The mine manager, Fred Evans, had read about electrical developments overseas and decided to use the water available in the larger left branch of Skippers Creek to generate electricity, which could then be transmitted to the mine itself over a considerable distance and over a ridge 800 feet high. A Pelton wheel was ideally suited to the high head available at Bullendale.

By October 1884, plans were being made to build, two miles up the left branch, a powerhouse that would allow the crushing of ore continuously for seven or eight months a year and the addition of a further ten stamps to the battery. Water from an open race would be carried down a bluff through a pipeline to the powerhouse below, and directed at high velocity through nozzles onto the Pelton wheels. Lines would carry the power across the gorge of the creek and over the ridge to the battery, where a large motor was installed.

Walter Prince arrived at Bullendale in December to report on the project, and in February 1885

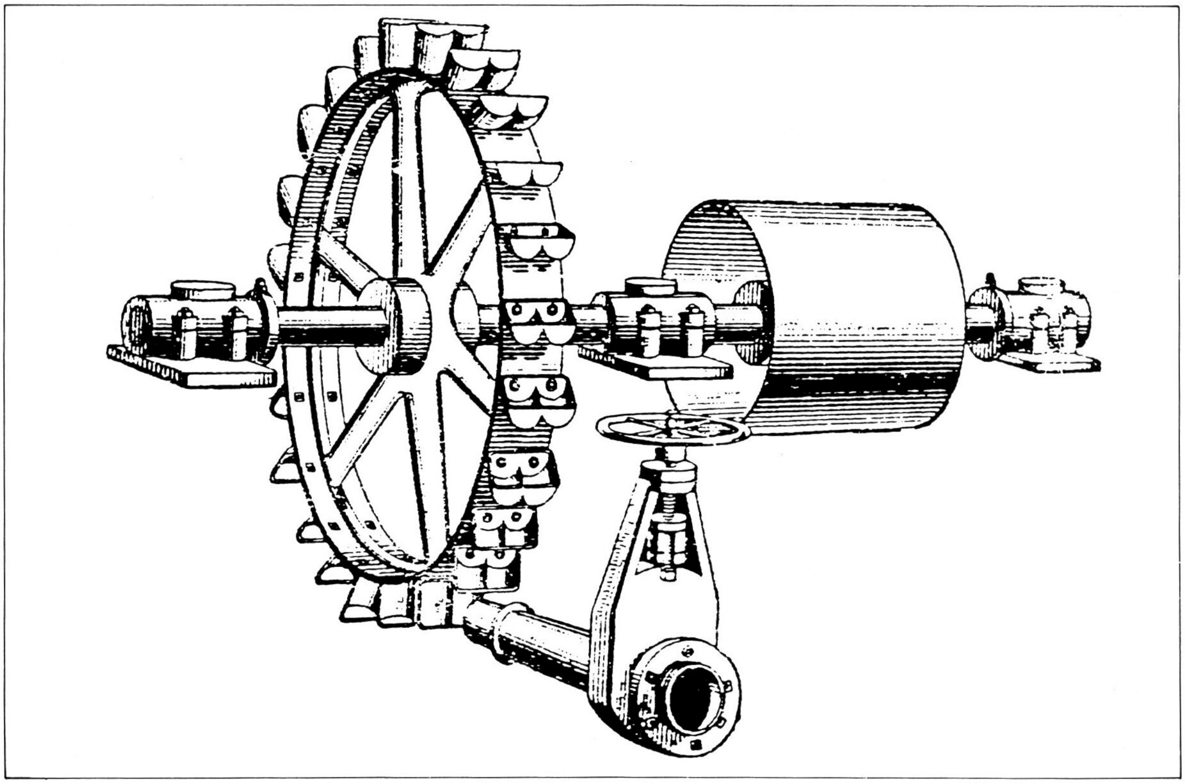


he agreed to install generators to drive up to twenty stamping heads, and to have them ready in six months. Fletcher supplied the machinery, while George Bullen, the mine's owner, undertook to rebuild the race to carry water to the powerhouse site.

Soon some 25 men were at work erecting the powerhouse, and the Pelton wheels were ready. After delays in the shipping of the generators from England, they were finally transported into the area in October 1885. Getting the dynamos — each weighing considerably more than a ton — two large Pelton wheels, and 700 feet of iron pipe

Left: The owners of the Phoenix mine at Bullendale built the first major hydro-electric plant in the country. This photograph shows the mine's powerhouse in the left branch of Skippers Creek, up the Shotover River, Central Otago. The building is at the base of a substantial bluff down which run two tapering wrought-iron penstocks.
Photograph courtesy of Mrs J. Cross

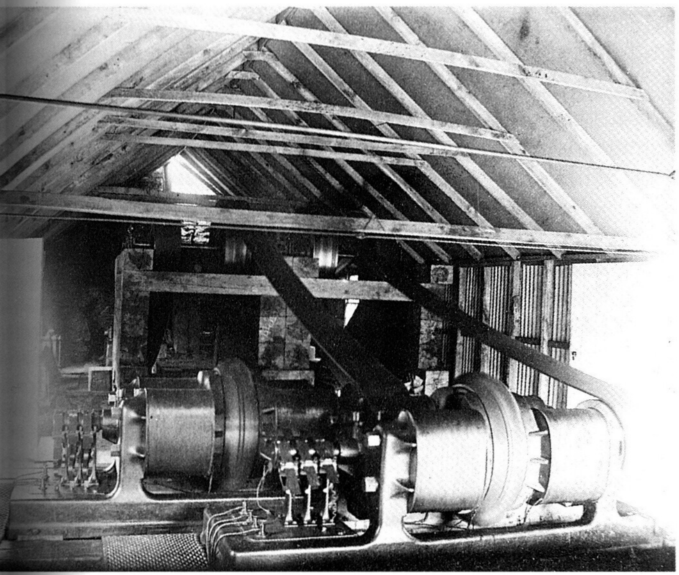
Below: A Pelton wheel of the type used at the Bullendale hydro-electric plant, manufactured under licence by A. and G. Price. These were six feet in diameter with a nozzle (shown in front) which produced a powerful jet of water two and a half inches in diameter. At Bullendale 50 hp was generated.
By courtesy A. and G. Price



along the narrow and precipitous track up the Shotover River and Skippers Creek to the site was a hazardous undertaking indeed. One dynamo was almost lost over a bluff. After months were spent getting the equipment in, it was being erected under Prince's supervision by December.

Meanwhile Fred Evans' son, James, had brought up another smaller dynamo from Dunedin, and linked it to a sixteen-inch Pelton wheel driven by water from the right branch of Skippers Creek. This was used to light the battery house — 'the whole of the battery being brilliantly illuminated . . . making it as light as day' — as well as workshops, the library, offices and Evans' residence.[9] Crushing was by now being carried out by the recently installed steam engine. By February 1886 Fred Evans had managed to start one generator and drive fifteen stampers, but was unable to reach full speed because an intermediate pulley was not big enough.

The two generators were then coupled together in accord with instructions from London but, since one acted as a motor, they produced very little power. Soon afterwards Prince fell from his horse on his way back to Bullendale from Queenstown and was seriously injured. The work was taken over by Fletcher, but problems remained. In July Fletcher's services were terminated; soon afterwards he became insolvent. A subsequent report by H. A. Gordon, Inspecting Engineer for the Mines Department, suggested that while the Pelton wheels produced 70 hp, only an effective 20 hp was available to power the battery because of technical problems in synchronising the two dynamos. The difficulty with such an experimental situation was that there was no ammeter in the country robust enough to measure the current and pinpoint what was going on! However, subsequent experiments by Fred Evans and his son, and the replacement of the solid armatures with laminated ones, solved the problem and allowed the generation of a total of 50 hp. With the system functioning properly, Evans was able to drive the entire 30-stamper battery, as well as providing lighting and powering a stonebreaker and a pair of air compressors for the winding engine, rock drills and air supply.



The two Pelton wheels at Bullendale drove two very large DC Brush Arc dynamos (shown here one behind the other) via intermediate pulleys and leather belting. Each dynamo was mounted on a massive cast-iron base and comprised a central armature, field magnets on both sides, and a commutator at the left-hand end.
Photograph courtesy of Mrs J. Cross

The mine continued to be worked by various owners until 1907, when the gold-bearing quartz was exhausted. The electrical plant, still in good working order, was scrapped during the First World War.

Reefton

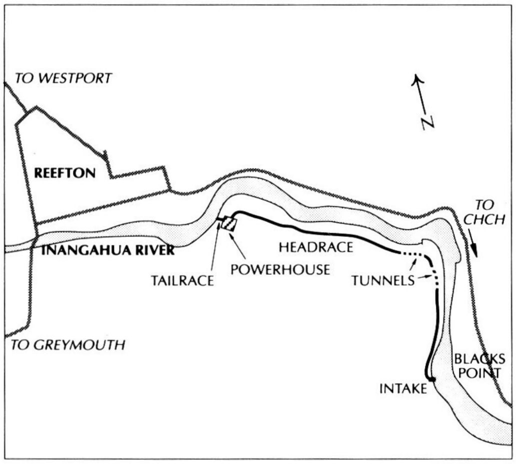
The possibility of electric lighting for the small but booming quartz gold-mining town of Reefton (population 1,100), which was well known for its speculative ventures, had been considered for some time.[10] Walter Prince was soon to establish a secure place for himself in the annals of New Zealand electricity by promoting there the first public electricity supply in New Zealand, only six years after the opening of the Pearl Street station in New York.

On 25 January 1883 a Mr Wylde, who had experience of electric lighting in Victoria, spoke at a public meeting in Reefton. This resulted in the formation of a committee to obtain estimates from the New Zealand Electric Light Company for plant to run 1,000 lights. Walter Prince was invited to advise, and arrived on 5 March. After investigating several alternatives, he suggested that the town harness the power of the Inangahua River through a water race rather than using a steam engine, and calculated that 100 hp could be obtained by this means. The committee was clearly serious about its plans, for it soon discussed forming a company to provide electricity and began investigating a water race. A deputation was sent to the borough council seeking support for constructing the water race, but the proposal eventually came to nothing because the company was refused the use of the town's water supply.

Nothing further was heard for a few years, although public interest must have been maintained, as 'Woodyear's Electric Circus' paid visits to Reefton in both 1884 and 1885. In November 1886 Prince once again appeared in town, accompanied by a blaze of largely self-organised publicity, just as an article, almost certainly self-penned, appeared in the *Lyttelton Times* reporting the successful scheme at Bullendale.

However dubious his abilities as a practical electrical engineer may have been, Prince was without doubt a very good salesman. He demonstrated the benefits of electricity by lighting four hotels, having linked his 1 kW dynamo to the brewery's steam engine. The *Inangahua Times* reported late trading that night. To reinforce his sales pitch, Prince gave a series of lectures and demonstrations on electricity to large audiences. Electricity — 'the modern Hercules' — was the 'greatest natural force the world has ever seen, brought under man's control and made his willing vassal', and would allow people to have 'bottled sunshine' in their homes. Little more than a fortnight later, on 6 December 1886, the Reefton Electrical Transmission of Power and Lighting Company was formed, with 65 shareholders, including Prince himself as a major shareholder. A contract to supply equipment to light 500 lamps was placed with Fletcher.

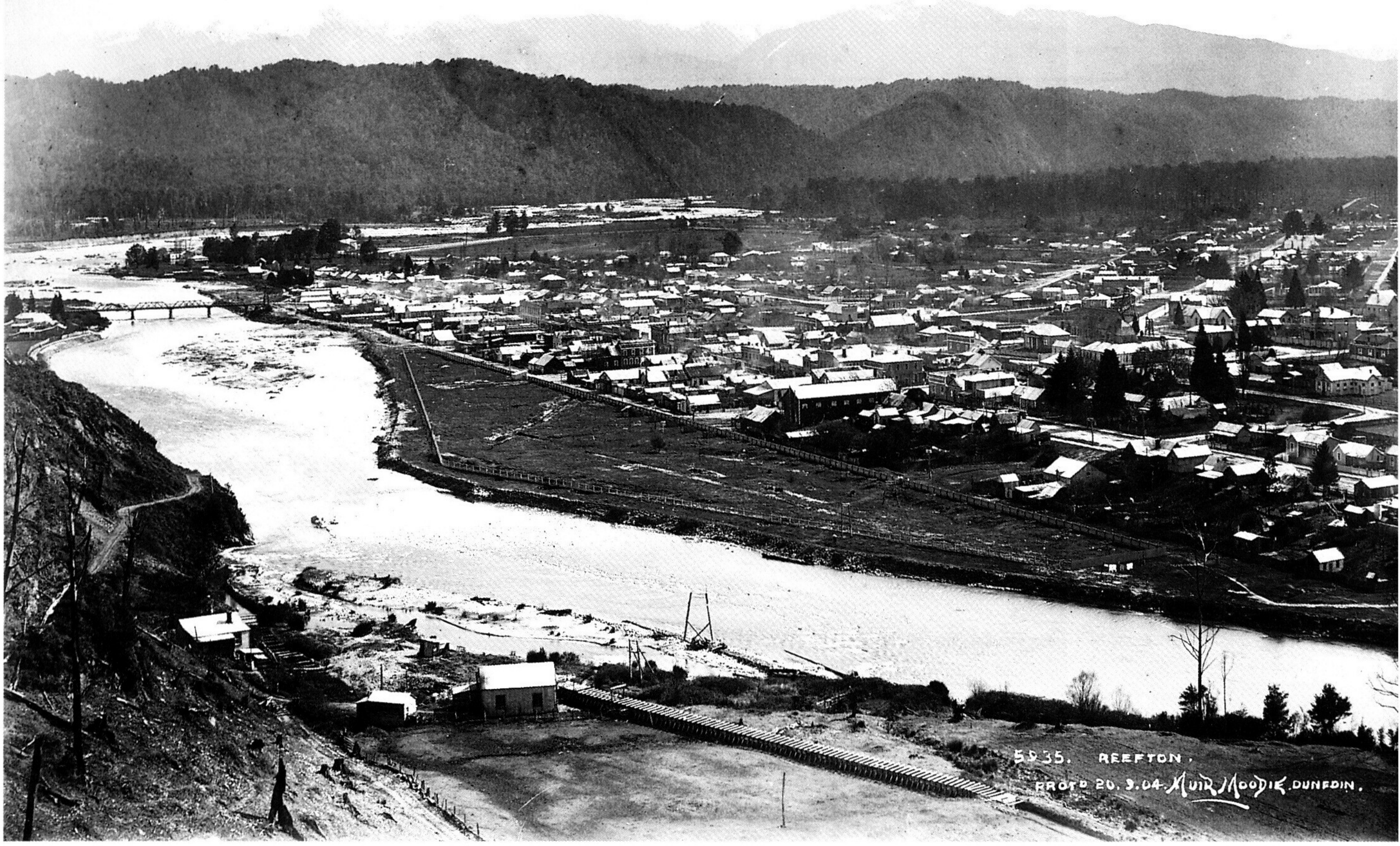
Reefton: Constructed 1887–88. Head 27 feet. The Inangahua River was diverted at Blacks Point into a race 6 feet wide and 5 feet deep, and carried a mile to the powerhouse across the river from the town. A 70 hp Rafel turbine drove by belt a 20 kW, 30/110-volt DC Crompton bipolar dynamo. In 1901 the dynamo was replaced by a 220-volt, 46 kW Fynn dynamo, and a steam engine was added to help drive the increased generating capacity. In 1908 the turbine was replaced by a 110 hp Boving horizontal turbine and the output was increased to 80 kW. In 1911 a new powerhouse was constructed and a 230-volt DC Lawrence Scott 100 kW generator installed. By 1920, in addition to the Boving turbine and Scott generator, there was a 75 kW GEC DC generator, a 25 hp Davey Paxman horizontal engine and a Marshall horizontal engine of 20 hp. In 1930 a standby diesel engine was installed, and in 1935 a new Boving turbine and Thomson-Houston generator.



Prince proposed to divert the waters of the Inangahua River into a race and down to a powerhouse across the river from the town. Construction of the race began in mid-1887 and was completed by the following January, despite problems with floods, slips and timber shortages. The machinery was installed by April 1888. Much correspondence resulted from the Post Office's concern for its wires. In December 1887 a licence was obtained under the Electric Lines Act to string overhead lines across the river to the town and along Ross, Shiel, Smith and Sinnamon Streets, Broadway and Buller Road, and underground cables elsewhere where there were telegraph wires. Unfortunately, the underground wires were laid in 'green' totara boxing, which often shorted in wet weather. The closest that the overhead wires got to telegraph lines was one and a half chains.

The first public showing of electric lighting was made on 1 August 1888, with some incandescent lights inside the powerhouse and an outside arc lamp which was played over the hills. As the *Inangahua Times* breathlessly reported:

> a large crowd of eager spectators lined the riverbank at the rear of the town to witness the display, and they were not kept long in suspense, for shortly after 7 p.m. the noise of the inrush of water to the turbine was heard by those near at hand, and almost at the same instant the bright luminous rays of the arc-light burst forth, lighting up the whole scene with strange but dazzling brilliancy. The light at first was somewhat unsteady, but after a little time became more fixed, though not always equally brilliant . . . The spectacle was, however, very beautiful — weirdly beautiful,



In 1888 the town of Reefton switched on the country's first public electric lighting. This photograph shows in the foreground the timber water race leading to the original powerhouse, from which power lines run across the Inangahua River to the town.
Burton Bros., September 1904, National Museum

> rendered so by the density of the shadows cast by surrounding objects. The outlines of the mountain ridges were as sable bands drawn across the luminous arc, and so altered the appearance of the landscape as to render it scarcely recognisable. About the station it was light as day, but the perspective was terribly confusing, and many people got into difficulties through trying to climb over the shadows of fences and walking through the substances . . . The whole of the machinery worked splendidly, and so truly that one would hardly know it was in motion but for the low whizzing noise of the belts rushing over the pullies, and the light scintillations from the dynamo.[11]

To mark the beginnings of public supply, some 50 lamps were lit for a crowd gathered at the Oddfellows Hall on 4 August. Prince, as agent, insisted on the use of Thomson-Houston lamps only.

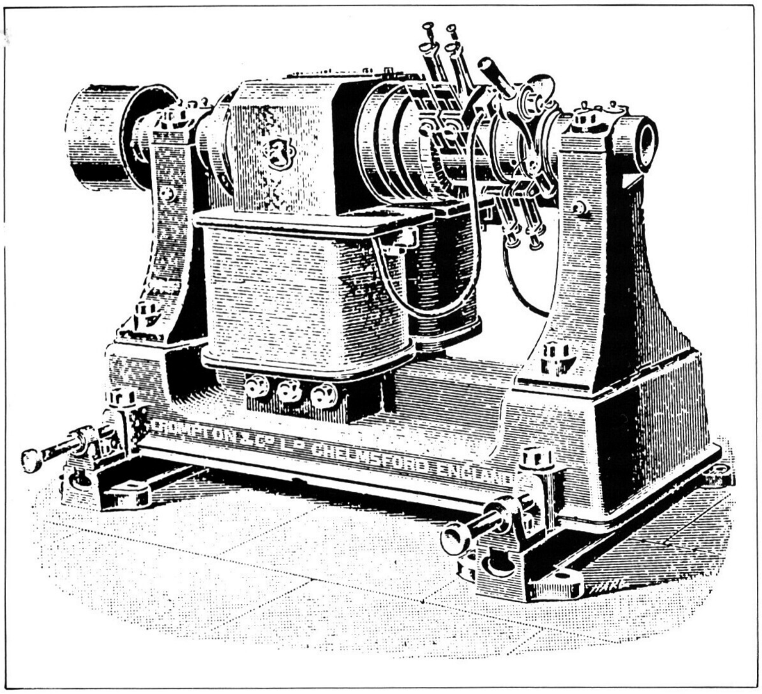
Electricity was now offered for sale to the public for the first time in New Zealand. It was available from sunset to sunrise, with consumers charged £3 per light whether power was used or not. Connections were made for £1 by the local plumber and tinsmith. By September 130 lamps were served, but supply was intermittent, particularly because of insufficient insulation of the underground cables. Prince was unable to solve the problems, and his services were dispensed with. Having forfeited his 2,000 shares in the company, he announced that he was leaving for the more important business of establishing electric trams in Auckland.

The company then hired J. J. Horton, who had just successfully lit the Melbourne Exhibition. He discovered that the wiring was of different gauges, and badly joined and insulated. The company had to spend a large amount on copper wire and superior Swan-Edison lights to fix the system. Horton was to remain with the company for fifteen years. Reefton enjoyed a brilliantly lit Christmas in 1888, with some 500 lights being supplied. The *Weekly Press* extolled the town:

> Reefton is making a proud name for herself. She above all cities in the Southern Hemisphere has started in the lead of utilising the electric light for the benefit of her inhabitants . . . Magnificent Melbourne, stately Sydney, august Adelaide, with ambitious Auckland, windy Wellington, critical Christchurch and discursive Dunedin, are all left far behind in the

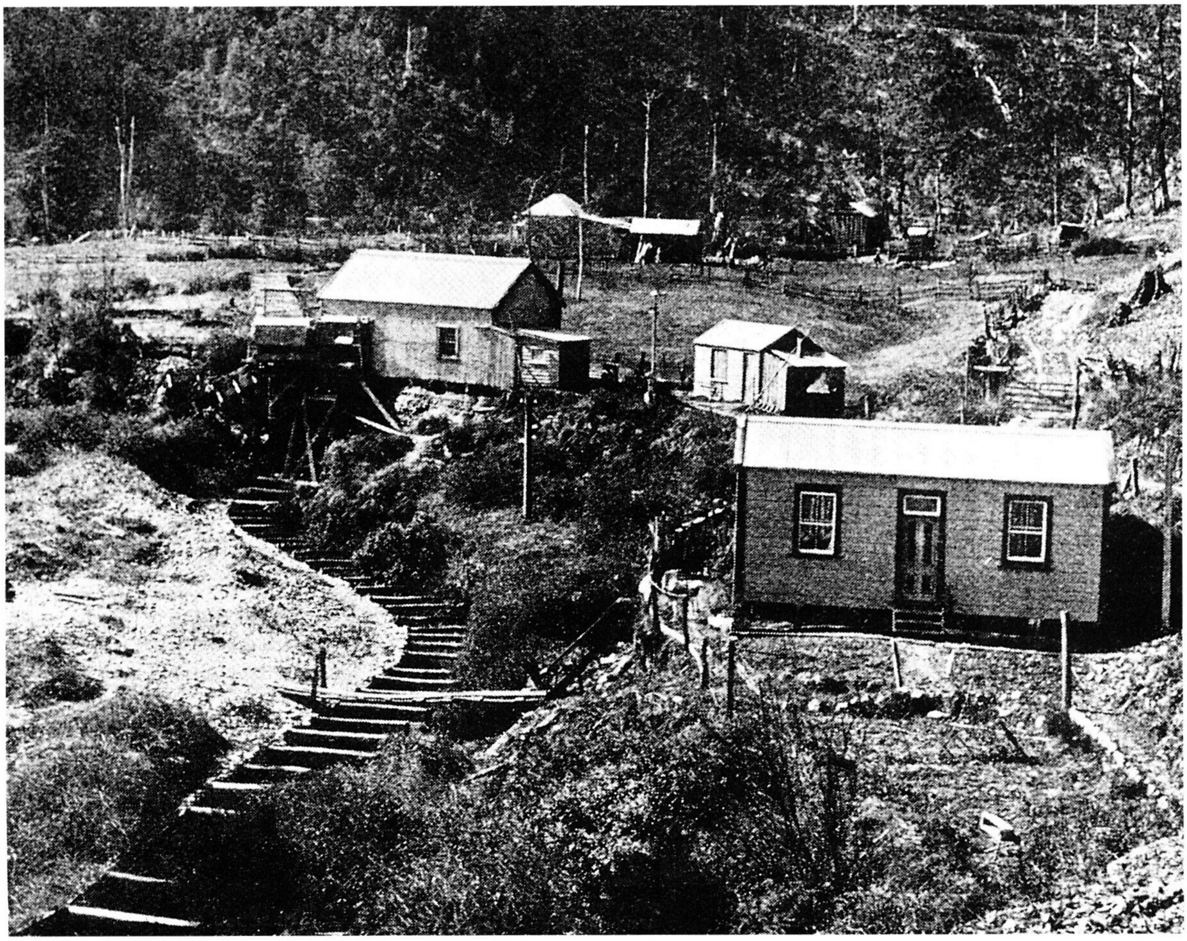
> march of progress, for Reefton has the electric light.[12]

Because no capital was available for the costly conduits required, the Telegraph Inspector gave permission in February 1889 for the erection of overhead wires where Post Office lines were crossed, provided they were properly insulated and at least eight feet away. The town had the distinction of issuing the first set of wiring regulations in the Southern Hemisphere, a single sheet devised by Horton and handwritten in copperplate by the company secretary. These were a telling commentary on Prince's installation.



Left: A Crompton bipolar dynamo similar to the one originally used at Reefton, which generated 20 kW at 30/110 volts and was driven by belt from a 70 hp Rafel turbine. This dynamo was replaced by a larger 220-volt 46 kW Fynn dynamo in 1901.
NZ Electrical Journal, 10 July 1934

Below: A closer view of the powerhouse and the tailrace leading water back to the Inangahua River.
Weekly Press, 5 October 1904, Canterbury Public Library

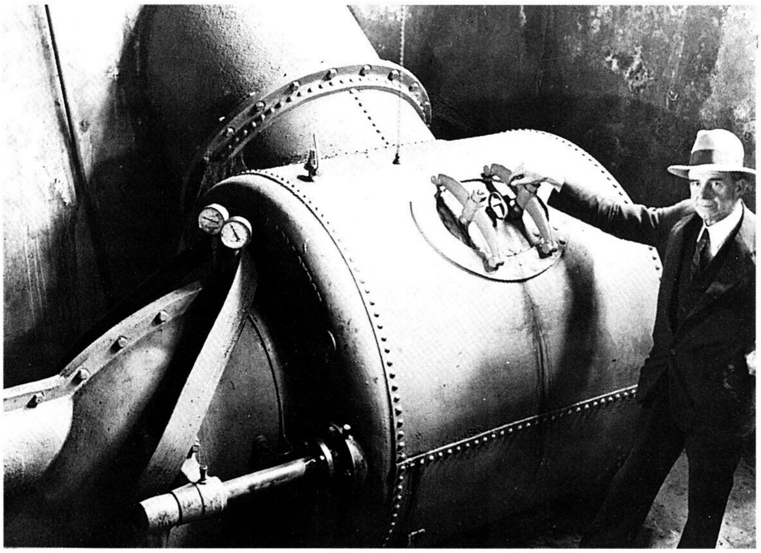


However, repairs to the water race had constantly to be made, and the company's costs continued to exceed its income. In 1892 a new company, the Reefton Electric Light and Power Company, was formed, and under the direction of Morris Levy, an investor in local mines, the position improved. At the turn of the century Walter Wilby, a mining engineer, took over its management, and the company began to make a profit and pay regular dividends. Later, power was made available all day on Tuesdays to allow ironing after Monday washing.

Over the years there were many changes in the equipment. In 1901 Wilby replaced the low-voltage Crompton dynamo with a new 220-volt dynamo. A steam engine salvaged from a wreck at Greymouth was added, as the increased generating capacity was beyond the power of the water turbine. This was fuelled by Reefton coal. In 1908 a more powerful turbine was installed, but in 1911 the whole plant was destroyed by fire. This resulted in the construction of a new powerhouse and the installation of a new generator.

In 1914 the distribution lines had their first official inspection by H. M. Millar, an Assistant Engineer in the Public Works Department. By this time the company had — without authority — extended its lines and was supplying some 300 consumers. All the lines were strung overhead, and the lack of insulation was apparently causing the Post Office some problems. Millar was horrified at the state of service connections and the number of broken insulators, and made especial mention of one particular pole in a paddock anchored by a reaping machine. Millar concluded his report by recommending that the company apply for a fresh licence, as the existing one did not include the standard regulations of the time. After considerable correspondence, eventual retrospective authority for the extension of lines was given in February 1916.

By 1920 complaints were being made to the Public Works Department, particularly by Dr E. H. Scott, about the voltage of the supply. Scott described having to use candles for his evening surgery. Millar inspected the system again and found that in many ways it did not comply with the 1915 regulations. He tested the voltage and found that it declined from 208 volts at the powerhouse to 134 volts at the extremity of the system, and was again dismayed by the state of lines and poles. Charges were still not made on the basis of usage through metering, but were flat rates for connection: private houses — first light 5s, second 1s 6d and subsequent lights 1s; business lighting — first ten lights 4s each, next twenty, 2s each, subsequent lights 1s; continuous outside lights — 5s each; 'six o'clock closing premises' — 2s 6d each; charging boards — 5s each; electric irons — 4s each. Radiators were 'not permitted on any account'.



The 110 hp Boving horizontal turbine that was installed in the powerhouse at Reefton in 1908.
Making New Zealand collection, Alexander Turnbull Library

The problems with voltage levels resulted from there being insufficient power to drive the generators, and were cured by the addition of another boiler. In the 1930s, as people acquired electric ranges, water heaters and electric heaters, the load increased rapidly. This pointed the way towards integration into the wider system, which involved complete rewiring and conversion to alternating current. In 1946 the Grey Electric Power Board purchased the company's assets, and three years later Reefton became part of the AC system.

Developments elsewhere

The four main centres followed very different paths in electricity generation and supply for lighting. The Municipal Corporations Act 1886, and especially its 1887 Amendment Act, helped promote the use of electricity for lighting. Municipal authorities were empowered to 'do all things necessary to light streets with electricity and to supply electricity for lighting purposes and motive power to the inhabitants'. The issue of electricity versus gas lighting became confused with that of municipal versus private generation and supply. Because of resistance to the major initiatives taken by private companies, the introduction of electric lighting was slow and halting. In Dunedin, where both the gasworks and the waterworks were in municipal hands, there was little impetus to instigate any electrical supply until the council itself did so. Only in Wellington, where private enterprise was given its head, was electric lighting established at an early date. By the 1890s much-improved and cheaper incandescent gas lighting provided strong competition.

The Wellington City Council first considered electric lighting in 1887 and, after trials involving Prince, asked for tenders.[13] In August 1888 the Gulcher Company was awarded the contract to light the city with 480 twenty-candle-power lamps. The system was single-phase AC of 100 volts at 80 cycles per second. This was probably the first use of AC current in New Zealand, and came very soon after the development of AC technology overseas. George Lauchlan, later the Wellington City Council's Electrical Engineer, was one of those employed to erect the system. The city provided, free of charge to the company, water from the mains to generate power, but was not obliged to maintain this supply in dry periods. (The use of water mains for electric lighting followed a practice common in Switzerland at the time.) Two stations were established, with a total of four 30 hp 'vortex' turbines driving 15 kW Gulcher single-phase AC generators and supplying lights in the Te Aro and Lambton Quay areas. When the lights were switched on in June 1889 someone was moved to pen: 'Tonight a thousand suns resplendent shine, / From Lambton's curve to Newtown's far confine'.[14] The Panama Street station was supplied from the mains in Featherston Street and discharged into the harbour, while the Manners Street station discharged into the Te Aro Stream. However, the plant suffered from a shortage of water and reduced pressure, the *Auckland Star* commenting parochially that 'the electric light is capable of no more illumination than a fat and healthy glow worm'.[15]

After two years the company went into liquidation following financial difficulties. The Manners Street station was closed and three larger 50 hp vortex turbines driving five AC generators were installed at Panama Street. In 1891 the company, reconstituted as the New Zealand Electrical Syndicate, applied under the Electric Lines Act 1884 to extend supply to private consumers.

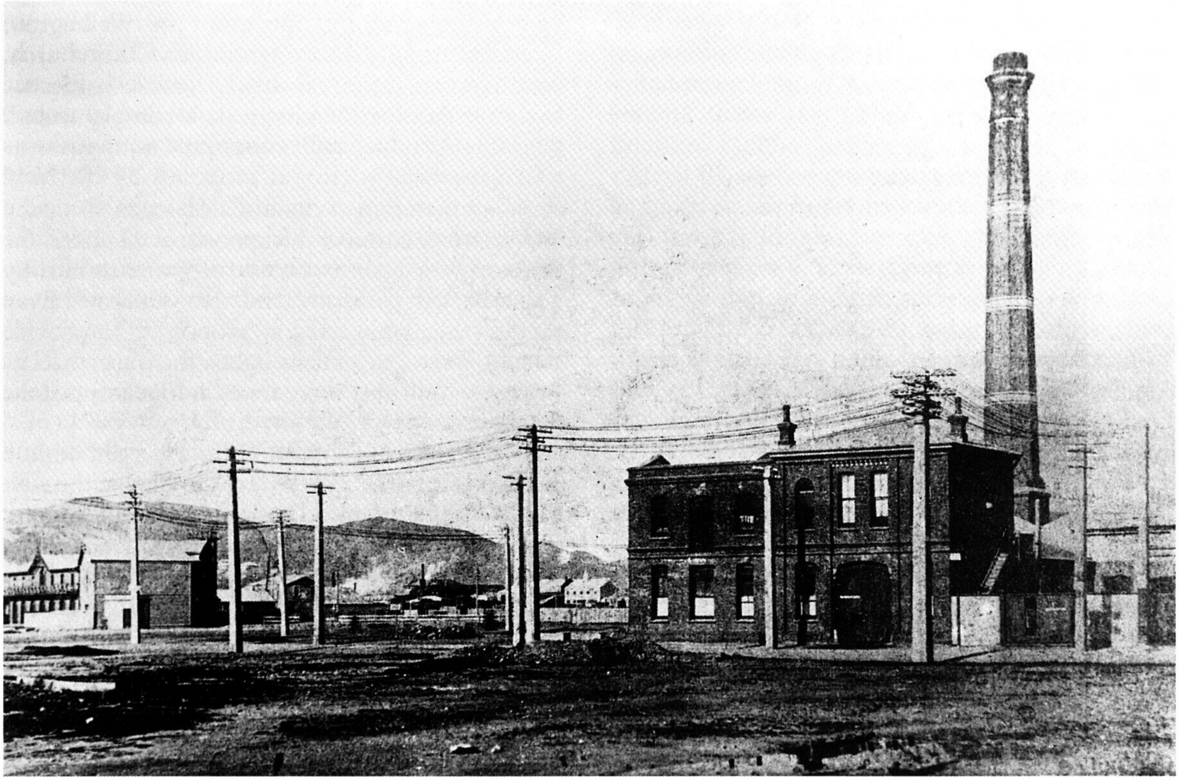
The syndicate also wanted to extend its business to other cities, and so promoted the introduction into Parliament of three private Electric Lighting Bills that would give it the right to develop electricity supply for Wellington, Christchurch and Auckland, and thereby enable it to become a major private generator and supplier of electricity. Mr De Castro, the company's chairman, came out from England to this end.

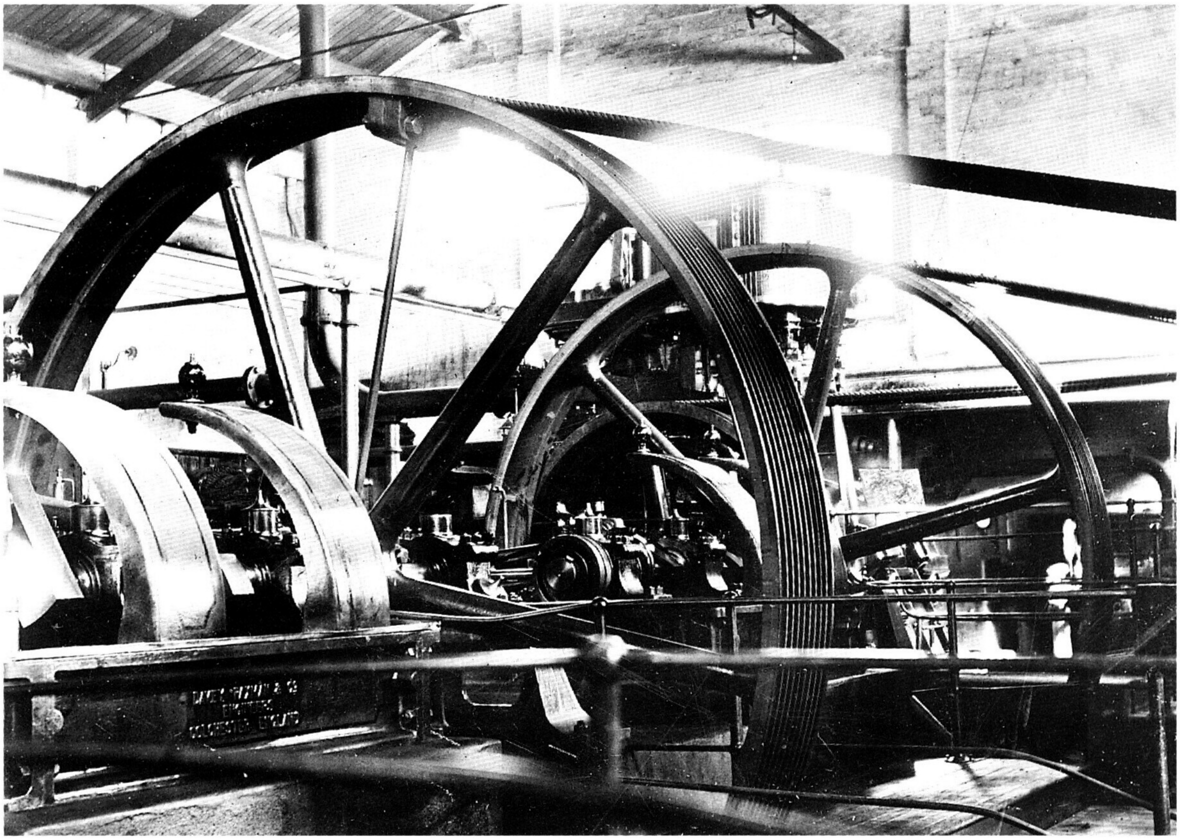
Although this scheme was supported by Wellington's city council and seen by some MPs as a means of breaking the monopoly of gas companies, there was also considerable political opposition to putting another monopoly into private hands, thereby reducing the powers of local authorities. The fact that the company was based in Britain and was sponsoring private bills in New Zealand's Parliament was also criticised. The three bills were enacted after considerable debate and the provision of safeguards. The Wellington and Christchurch Acts empowered the syndicate to construct and operate generating plants, but also gave each council the right to purchase the plant after ten years on the basis of the capital expended and up to 10 per cent profit per annum, or after 21 years on the basis of the value of the plant and 'goodwill'. This provision was similar to that of the 1882 British legislation, which so restricted the development of electricity there. The much shorter Auckland Act, which was strongly opposed by its city council, merely decreed that a ratepayers' poll should be taken on the issue, and that if the proposal had not been endorsed within a year, all rights would lapse. It appears that no such poll was taken.[16]

The Electrical Syndicate was undeterred, at least in Wellington, where in 1893 the company installed a new steam plant between Harris and Mercer Streets, on the site of the present public library. Four Davey Paxman boilers and horizontal steam engines drove 75 kW Gulcher AC

Opposite above: Wellington city was the first major centre to supply electricity for public lighting, in 1889. The system was built and operated by the Gulcher Electric Light and Power Company, later the New Zealand Electrical Syndicate, which in 1893 installed generating plant in this brick building on the site of the present public library in Harris Street.

Opposite below: Wellington's Harris Street station comprised four Davey Paxman boilers and horizontal reciprocating steam engines, which drove 75 kW Gulcher generators by rope via twelve-foot flywheels.
Making New Zealand collection, Alexander Turnbull Library



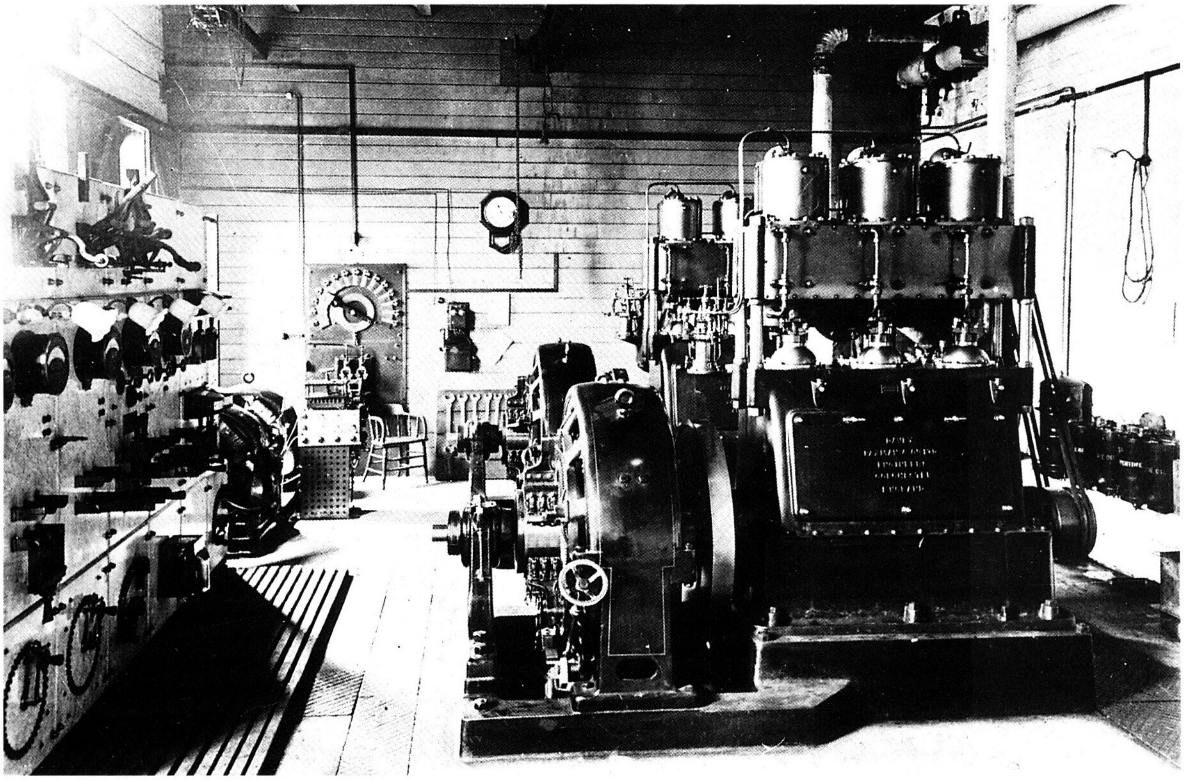


generators by rope via large flywheels, and a smaller steam engine drove a 25 kW generator. This station initiated supply to private consumers, who were charged 16s per annum for each eight-candle-power lamp, or 11d per kWh. Single-phase AC power was generated at 2,000 volts and 80 cycles per second, and stepped down to 105 volts. By 1894 the company had the contract to light Parliament, despite opposition from Dr Lemon, who favoured use of the plant at the Government Printing Office. Wellington's plant was increased in capacity to 1,725 kW by 1906, with the addition of a number of other steam engines, including three vertical Bromley and Lindley engines coupled directly to Westinghouse generators. (See Chapter Three for subsequent developments.)

Despite considerable early interest, Christchurch was late in obtaining a municipal supply of electricity.[17] After calling for tenders for street lighting in 1888, the city council decided not to proceed. In 1889 the Gulcher Company, which had just started its operations in Wellington, offered to supply street lighting in Christchurch, but nothing came of this. The 1891 Electric Lighting Act for the city was not implemented, the council finding itself committed to its gas contract in spite of accepting proposals by the New Zealand Electrical Syndicate. The gas company had exerted considerable pressure. In 1892 the decision was again in favour of gas after bids by both the gas company and the syndicate. Even though the syndicate was proposing to provide twenty times as much light, the fact that its scheme would cost three times as much tipped the balance.

Matters remained quiet for a time, although a number of private plants were installed in the city. In 1898 the council became committed to a 'scheme of works' that included electrical generation and supply. In 1899 Arthur Dudley Dobson prepared a report on the Waimakariri River, and this led to the passage in 1902 of an Act empowering the council to raise loans and build a scheme on the river.

However, these proposals went no further, and Christchurch in fact began with steam generation in 1903 from its rubbish incinerator in Armagh Street, which supplied the central-city area. The



Christchurch, after long discussions, eventually built a small power station attached to its Armagh Street rubbish incinerator. This opened in 1903, and comprised two Davey Paxman steam engines driving Westinghouse generators, shown here in 1905 with the switchboard at left.
Canterbury Museum

plant, comprising two Davey Paxman steam engines driving 100 kW Westinghouse generators, was installed by Noyes Brothers of Sydney. Lawrence Birks, who was to be an important figure in national power development, was appointed as the city's Electrical Engineer in March 1903. The plant's capacity was soon inadequate. Another 150 kW generator was added in 1905, and later that year a boilerhouse for a new coal-fired boiler was built next to the destructor, in recognition of the fact that the steaming capacity of the destructor plant was inadequate. In 1910 two 200 kW steam-driven generators and another coal-fired boiler were added.

In 1905 the Christchurch Tramways Board built its own plant, which comprised two Curtis steam-turbine sets of 500 kW each. These were the first steam turbines in New Zealand. Another unit of the same size was added in 1907, and in 1910 a 1,000 kW turbine was acquired.

Although the question of public electricity supply was debated in Auckland from 1882, little happened for some time.[18] Proposals to light Queen Street wharf made in 1883–84 were not implemented. In 1886 the first licence under the Electric Lines Act 1884 was issued for lighting Queen Street wharf, but in fact gas was used.

There was much activity in 1887. Prince attempted to interest the Auckland City Council in electric lighting, as did E. A. Ashcroft and Company of Wellington, who submitted rival proposals for street lighting and gained a contract to erect four arc and six incandescent lamps in various city locations. However, a fire at Crompton's works in England prevented prompt delivery of the equipment, and the contract was cancelled. J. C. Firth successfully demonstrated electric light in Queen Street for two weeks from Christmas Eve 1887. Six arc lights were powered from his highly mechanised and advanced 'Eight Hour' roller flour mill, but Firth failed to persuade the city council to accept his proposals.

In May 1888 Prince was again in the city, proposing terms for street lighting on behalf of the Thomson-Houston International Electric Company. In August he offered to supply power for the trams, having come over from Thames, where he had been promoting a proposal to light the town. But these efforts came to nought, and Prince disappeared from sight.

A lighting contract was subsequently awarded to the Auckland Gas Company, which had been thwarted in attempts to acquire the right to supply electricity in 1882 and 1889. In the 1890s the city council resisted, including opposition to the 1891 Act, any attempts by private enterprise to establish generating plant, and to this end it had passed the Auckland Electric Lighting Act 1900, which gave itself exclusive generating rights.

In 1902 the adoption of electricity for trams highlighted the city's overall backwardness in its provision. The following year the council began to take power from the tram company's plant for arc lights in Queen Street. By this time a number of businesses had their own plants. After a series of reports, the city council began to construct its own plant in 1906 (see Chapter Three).

After Bullendale, the gold-mining industry remained at the forefront of the industrial use of electricity. In 1889–90 the Sandhills Gold Mining Company began operating what has been claimed as the first electrically powered and lit dredge in the world, on the Shotover River not far from Bullendale.[19] The dredge had been powered previously by a coal-fired steam plant, but the cost and difficulty of transporting coal into Central Otago had been a major problem. The dredge was designed by R. C. Jones, Electrician for the Union Steam Ship Company and later a founder of Turnbull and Jones. The generating plant was located one and a half miles up-river from the dredge, and was erected by Fletcher, who had resurrected his company. The water was taken from Rapid Creek, carried by a race to a surge tank, and delivered through 1,320 feet of tapering pipeline to a four-foot Pelton wheel operating on a head of 520 feet. The Pelton wheel drove by belt two Brush DC Victoria dynamos with a total output of 52 kW at 1,300 volts. Flexible cables played out from drums allowed the dredge to move up and down the river. In 1891 another dredge, at Six Mile Beach in Southland, was electrically lit, with power being provided by a Tangye suction gas engine.

Richard Seddon, as Minister of Mines and Public Works in the early 1890s, was disappointed that more use was not being made of New Zealand's water resources. During a visit to the Coromandel goldfield in 1891 he considered the possibility of using electricity for crushing quartz, and in his annual Mines Department report for that year he exhorted the industry to follow the examples of the Phoenix mine and the Sandhills dredge. Mines Department annual reports and engineers such as H. A. Gordon repeatedly encouraged the use of electricity for both coal and gold mining in the 1890s. In 1893 Fletcher and Gordon reported on the feasibility of providing a centralised generating plant to resuscitate mines in the Kuaotunu and Thames districts; they considered transmitting AC current at 10,000 volts some twenty miles from the Waiwawa River, but the mining companies were not prepared to co-operate.[20]

The first recorded use of electricity in a coal mine was at Brunner, where in 1891 a plant was installed to transmit power to the underground workings. In 1893 electric lighting was installed at the Kaitangata mine. By the turn of the century the Millerton colliery had lit its Mine Creek surface works by electricity, and the Blackball colliery had installed electric pumps.

By the mid-1890s the gold-mining industry was showing more interest in electricity. In 1895 the Premier mine, near Macetown in Central Otago, followed the example of the Bullendale Phoenix mine with a similar type of plant. At this time the Thames-Coromandel field experienced a boom, with quartz mining being revolutionised by the invention of the cyanide extraction process. From 1895, large-scale English capital began buying up local mining companies, and by 1900 all the major Thames mines were lit by electricity.

The boom coincided with the emergence of the Waihi Gold-mining Company, which had first been floated in London in 1887. This company, which became the country's largest employer and largest single industrial user of power, played a vital part in developing the industrial use of electricity. The company installed a Victor 'reaction' water turbine (suitable for a low head), rather than a Pelton wheel, at Waikino in 1896. In 1898 the giant 'Victoria' battery of 100 stamps was constructed at Waikino. This was at first driven directly by two water-powered turbines, but in 1902 the company installed two 50 kW 220-volt DC generators driven by water turbines to power electric motors for the battery, which now comprised 200 stamps.

By the turn of the century a number of electric dredges were working on the Clutha River. The Fourteen-mile Beach dredge, operating by 1900, may well have been the first use in New Zealand of three-phase AC current. It was also designed by Jones. A powerhouse was built about seventeen miles down the Clutha from Alexandra. Water was led from a creek some four miles away by a wooden flume and 1,500 feet of iron-pipe penstock. A head of about 300 feet drove a Pelton wheel coupled to a 150 hp three-phase AC Brown Boveri generator, which supplied power at 2,300 volts and 50 cycles per second. In 1901 the Earnscleugh No. 3 Dredging and Electric Power Company constructed an electric dredge, for a long time the largest dredge in the country, which was driven by three-phase AC power generated more than four miles away in the Fraser River by a 200 hp 50-cycle 5,000-volt system. This dredge worked for more than twenty years.

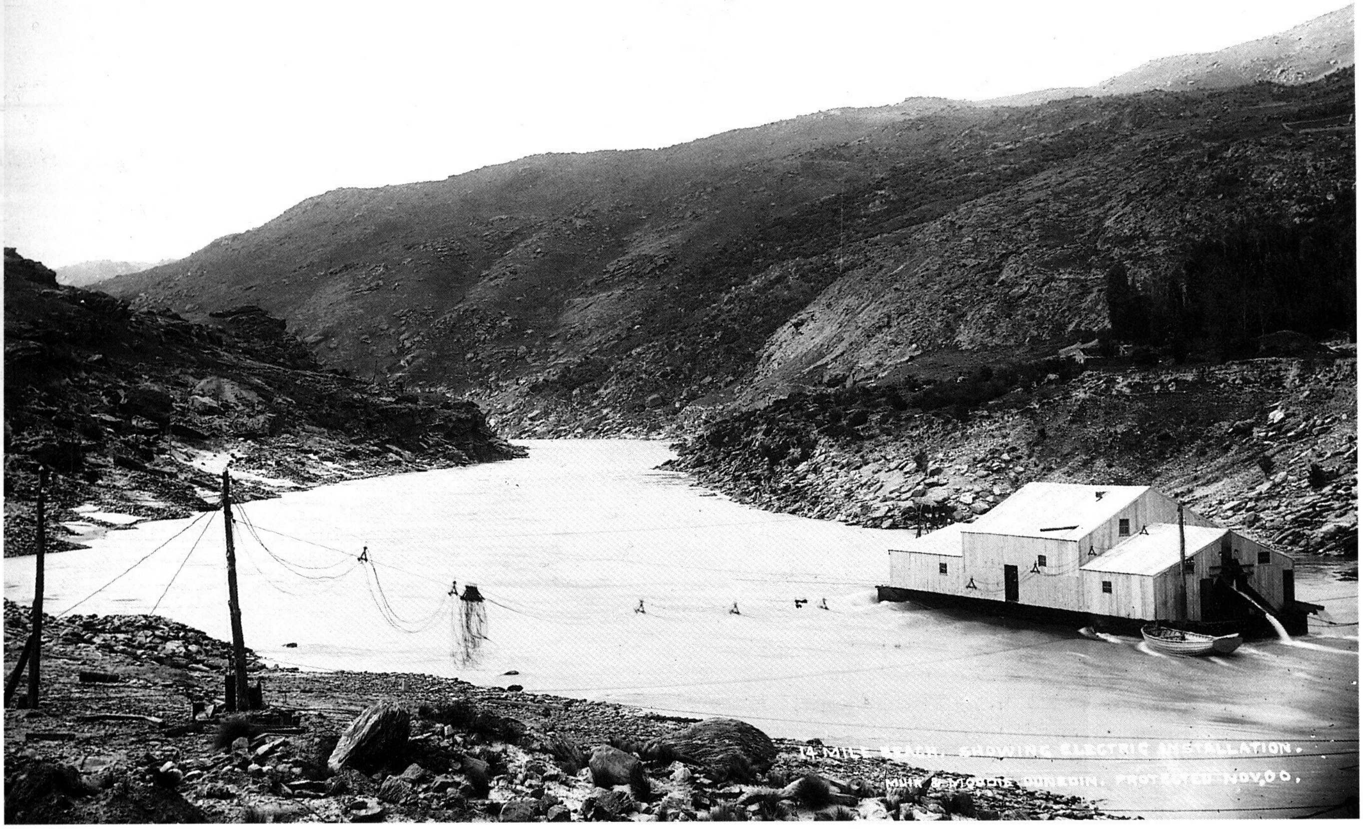
In 1905 the Waihi company built an advanced power station at its Grand Junction mine, where three 580 hp steam turbines drove directly connected Brown Boveri three-phase AC generators for pumping and winding gear.[21] This was the first electric winder in the country. In addition to this, the company used a Pelton wheel, two other steam engines and a gas-producer plant for generating electricity. At this time the Waihi company, which employed about 1,500 men in its mines, dwarfed other local mining companies and was amongst the world's largest producers of gold. Further electrification followed with the construction of the Horahora hydro-electric scheme on the Waikato River between 1910 and 1913 (see Chapter Two).

By 1899 the Waitekauri Cross Gold-mining Company near Thames had installed electric power, using a Pelton wheel and two belt-driven compound dynamos. By now many companies lit their mines, the use of electricity for this purpose being particularly attractive because of its safety. Like the Waihi company, Ross Goldfields Ltd built its own power station, of 750 kW, at Kaniere Forks between 1907 and 1909. Power was transmitted 25 miles to pump water out of the mines at Ross.

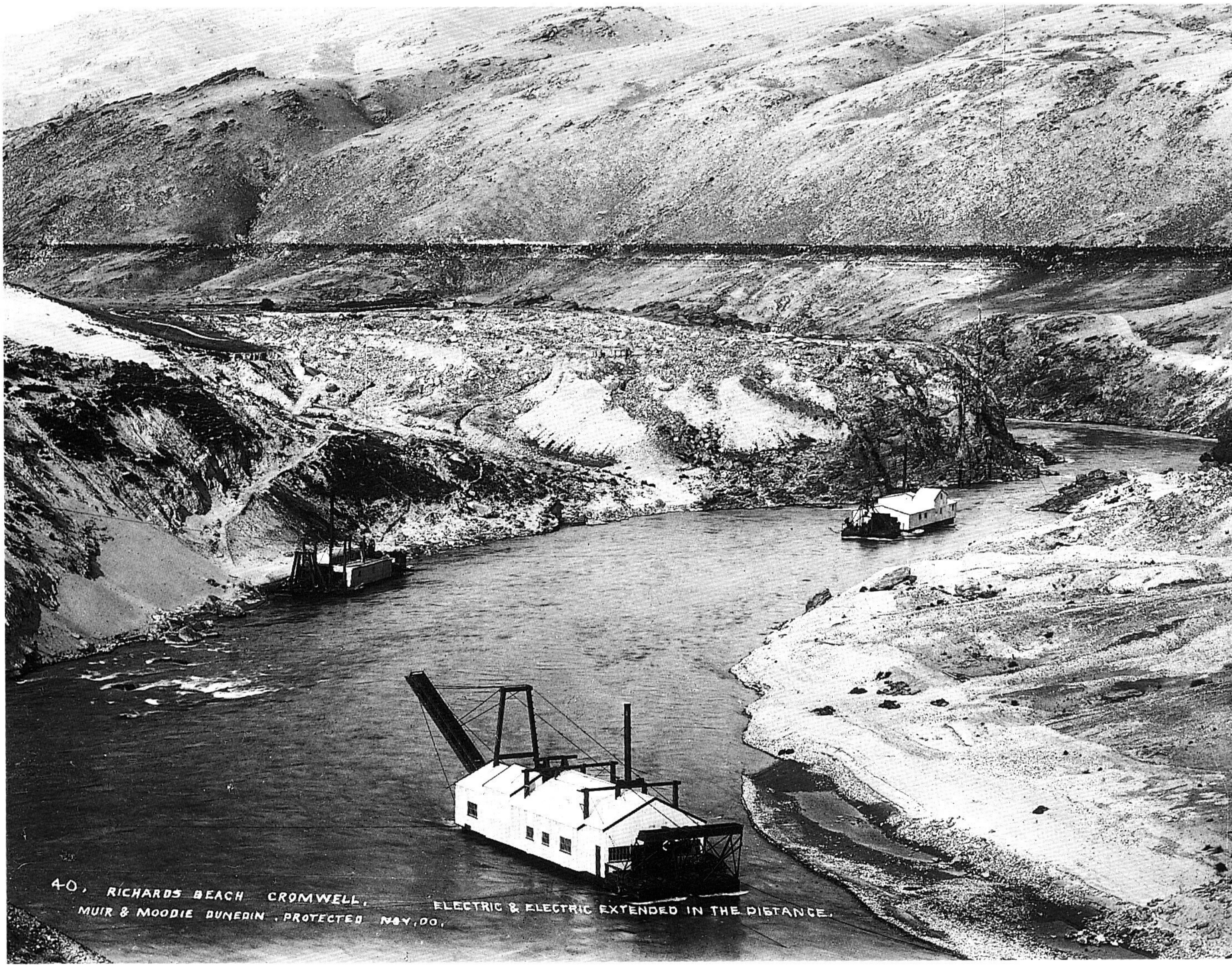
Other industries were also beginning to make use of electricity. The first were probably the Southland Frozen Meat Company and the

Opposite above: The Fourteen-mile Beach electric gold dredge on the Clutha River, showing power cables leading from the bank to the dredge. This dredge, which operated from 1900, may well have been the first example of the use of three-phase AC current in New Zealand. Power was supplied at 2,300 volts and 50 cycles per second.
Burton Bros., November 1900, National Museum

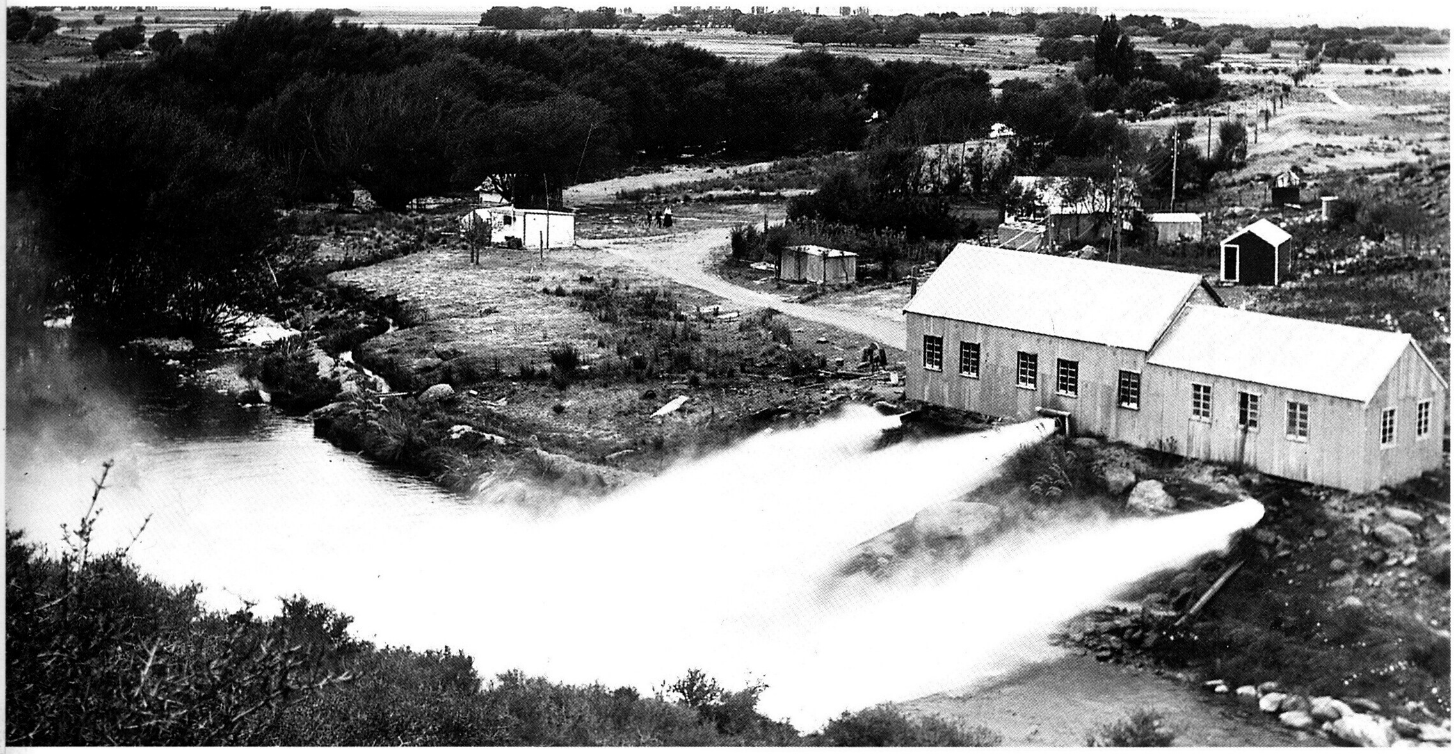
Opposite below: A number of gold dredges adopted electricity at the turn of the century. This photograph shows the 'Electric' and 'Electric Extended' dredges working at Richards Beach, near Cromwell on the Clutha River.
Burton Bros., November 1900, National Museum



14 MILE BEACH. SHOWING ELECTRIC INSTALLATION.
MUIR & MOODIE DUNEDIN. PROTECTED NOV,00.



40. RICHARDS BEACH CROMWELL. ELECTRIC & ELECTRIC EXTENDED IN THE DISTANCE.
MUIR & MOODIE DUNEDIN. PROTECTED NOV,00.



In 1901 the Earnscleugh Gold Dredging Company built a large electric dredge, and this power station on the Fraser River, which comprised a 200 hp, 50 cycles per second, 5,000-volt system. This photograph, taken *c.* 1914, shows the turbines discharging back into the Fraser River.

Otago Central Electric Power Board, photograph courtesy of Mr I. Paterson

Mataura Paper Mill, on opposite banks of the Mataura River. In 1890 the meat company installed a 450 hp vertical Hercules turbine, which later also supplied the nearby towns of Gore and Mataura. The paper mill installed a 310 hp vertical turbine in 1893.

By the turn of the century some fifteen factories producing goods such as aerated water, cordials, furniture and clothing, and printing works were using electricity as a source of motive power.[22] Wellington, perhaps because of its early adoption of a public supply, had eleven such factories, Otago three, and Canterbury one. But most electricity use was still for lighting.

The Hawera Gasworks and Electric Lighting Act was passed in 1897 after a long debate about private company monopolies, and despite opposition from Seddon, who thought that only local authorities should have such powers. After the passage of another private Act in 1898, the Stratford Electrical Supply Company built a small hydro-electric plant on the Patea River that year, making Stratford second only to Reefton in the development of public lighting in smaller towns. The following year the trustees of Parihaka Pa in southern Taranaki made street lighting available there to complement its formed roads and piped water supply (the generator was driven from the latter). Dairy factories soon took advantage of electricity for lighting and for running separators and butter churns.

In 1902 Patea commissioned the first municipally owned generation and distribution system in the country, which comprised a 40 kW hydro-electric station with 3,000-volt transmission lines running three miles to the town. The following year the Hawera County Electric Company began operating an ambitious scheme, an early three-phase system that had the highest voltage (5,500 volts) then in use in the country. The Waingongoro River was used to power a double-ended turbine driving a 90 kW AC generator at each end. Power was supplied not only to Hawera, but also to Manaia, Kaponga, Normanby and Eltham, and to farms in the district. By 1906 growth demanded the installation of another turbine and a 200 kW Brush AC generator.

Meanwhile the Dunedin City Council was determined that electricity generation and supply should be in municipal hands. Dunedin had not seriously considered embarking in this direction until the tramway company's concession expired in 1898. The council purchased the tramways and decided to electrify the system. (The Tramways Act of 1894 had empowered local authorities to construct tramways and drive the trams by electricity.) In 1900 the council operated the country's first electrically driven trams, using electricity generated by a steam plant. Dunedin now took the lead by constructing, on the Waipori River, New Zealand's first large-scale hydro-electric project.

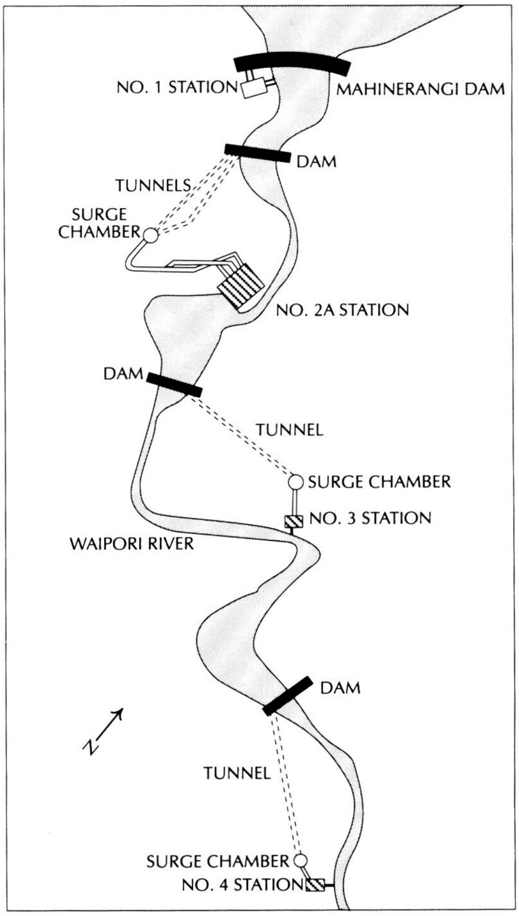
Waipori

Waipori was for its time a very large hydro-electric scheme, and its success soon led to demands by other cities for similar projects.[23] The Dunedin City Council has continued to develop the Waipori River for more than 80 years, as technology has increased the capacity of equipment and enabled more water to be brought to Lake Mahinerangi from ever further afield. The Stuart Sidey diversion, opened in 1984, brings water from Deep Stream through tunnels and pipes to the Lammerlaw Stream, which flows into the lake.

There had been gold mining in the area since 1862. By the end of 1864 more than 3,000 miners were working on the river and its tributaries. The river rises in the Lammerlaw Range and falls slowly as far as the Waipori Gorge, where it suddenly drops 730 feet in two and a half miles. The gorge is thus an ideal site for a hydro-electric scheme.

The first plans to develop the river came in 1900, at a time when more than a dozen gold-

Waipori: First installation constructed 1903–07 (subsequently known as No. 2 station). 'Efficient' head 665 feet. Water was diverted from the Waipori River by a timber crib dam and originally conveyed to a penstock by 1¾ miles of wooden fluming. A 4,700-foot-long tunnel replaced the flume in 1911. Two Pelton wheels drove two 1,000 kW 2,400-volt three-phase AC generators. Later there were six 1,000 kW generators. Power was transmitted at 35 kV 28 miles to Dunedin by duplicate lines. A 50-foot-high earth-fill dam was built at Bridge Creek in 1907, and a 41-foot-high concrete arch dam was built at Pioneer Creek in 1910. A concrete gravity dam on the Waipori River was completed to a height of 38 feet in 1923 and later raised to 60 feet. The six generators were replaced by others of about 3,000 kW, and a further unit was added to bring the total capacity to 21,400 kW. In 1931 the Mahinerangi arch/gravity dam was completed downriver of the old dam to a height of 67 feet; it was raised to 110 feet in 1946. The powerhouse associated with the dam (No. 1 station) generated an additional 3,000 kW. In 1954 No. 3 station (head 166 feet, 6.4 MW) and in 1955 No. 4 station (head 186 feet, 7.2 MW) were built further downstream. Both were operated by remote control. The original station was demolished in 1980, having been replaced by a new station of 56 MW. In 1983 a new station of 10 MW replaced that at the Mahinerangi dam site. The current total capacity is 83 MW.



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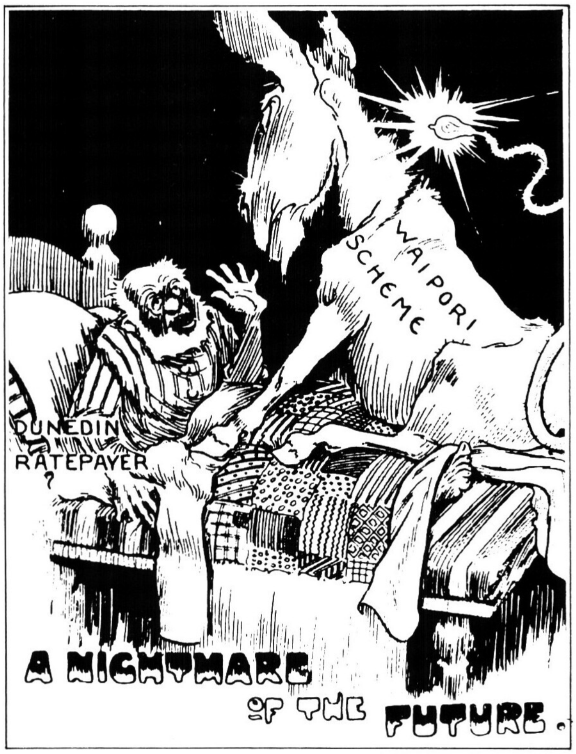

WAIPORI SCHEME
DUNEDIN RATEPAYER ?
A NIGHTMARE OF THE FUTURE.

As this cartoon suggests, the first Waipori power scheme faced considerable opposition. However, it proved a great success and not a burden on ratepayers. This scheme, which still operates today in a greatly extended form, was to set Dunedin apart from other major centres in that the city continued to generate a substantial proportion of its own electricity.

N. Rennie, *Power to the People*

mining dredges were operating on it. Coal for the steam-driven dredges was costly and difficult to transport over the tracks from the railheads at Lawrence and Outram. In that year John Lawson, a miner, applied and secured (free of charge) water rights for 80 cusecs for hydro-electric development for electric dredging. Lawson failed to interest Dunedin businessmen in his project, and sold his rights to W. E. Richardson, a flour miller in Outram Glen who had already installed electric lighting in his mill and supplied power for street lights for the township of Outram in 1898.

Richardson was more successful, and in September 1902 the Waipori Falls Electric Power Company was formed. The company realised that it could supply electricity to Dunedin and surrounding districts, but would have to confront a determined city council. Nonetheless, water-race and power-line routes were surveyed and construction began in early 1903. Meanwhile, the city council had chosen — controversially — a much smaller source of power in the Lee Stream for its new electric tramways. Debate over the two proposals raged for more than a year. In 1904 the company sought to put through Parliament a private Act enabling reticulation to supply the city and other local authorities, but the city council was not prepared to allow this and there was a bitter fight before the Local Bills Committee. After the contractor for the Lee Stream project withdrew from it, an agreement between the council and the company was finally reached. The council purchased the company's water rights and assets for a tidy sum as a condition of the bill's passage. Work proceeded and negotiations began for the sale of power to the Roslyn Tramway Company, to the government for the Hillside Railway Workshops, and to county and borough councils.

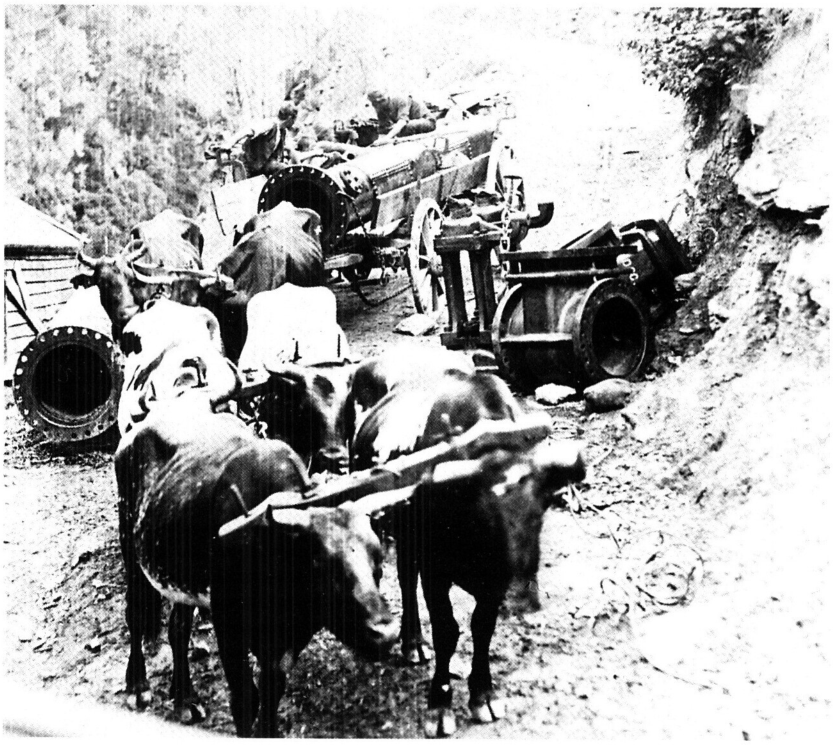
Noyes Brothers of Sydney, who were installing Dunedin's new electric tramway system, were engaged to complete the Waipori scheme, which was now modified to cope with a larger load and give a more reliable supply. The transmission lines were duplicated to minimise any interruptions to supply. Water was diverted from the river by a timber crib dam, and ran along a flume made of local native red beech and built on benching cut out of the sides of the gorge.

The plant was opened on 27 April 1907. However, because there was no storage for the scheme, there was insufficient water to run both generators at full capacity continuously, after a season of abnormally low rainfall. In the first year of supply there were serious interruptions to generation when sheep damaged the flume by dislodging rocks from the hillside above it. The flume was replaced by a tunnel, begun in 1908 but not finished until 1913.

By the end of 1907 it was clear that extensions were needed. Tributaries were investigated for their water-storage potential, and an earth dam was built at Bridge Creek, forming Loch Loudon in 1909. Two years later one of the first of the arch type of concrete dams in New Zealand was built at Pioneer Creek, a few miles to the west and with a larger catchment, and Lake Luella was created. In 1910 the Waipori plant's capacity was doubled to 4,000 kW to meet the steadily increasing load, and a further extension of 2,000 kW had to be made in 1913, by which time the Taieri Plains had been reticulated. Equipment was transported to the site with some difficulty, a ten-ton stator requiring a twenty-horse team to haul it.

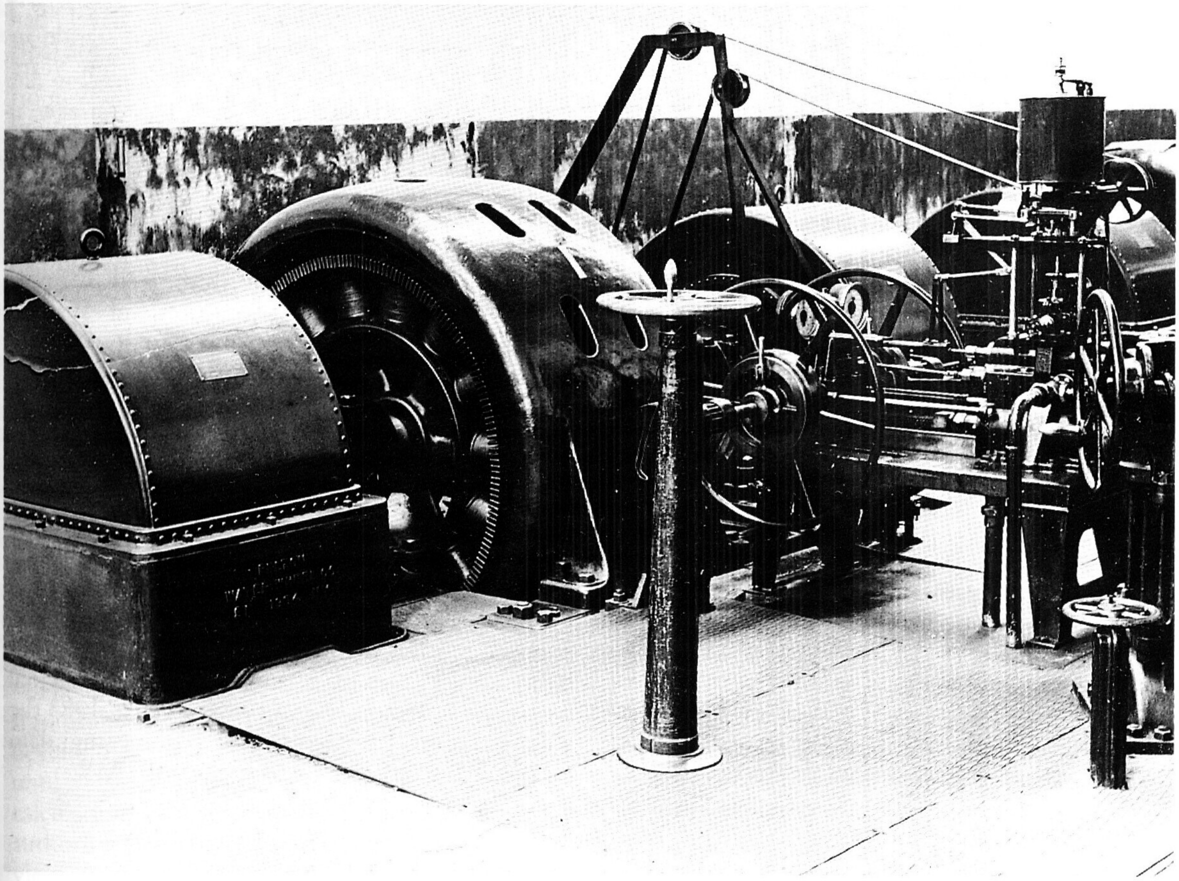
Ironically, gold mining now proved to be a major constraint on the scheme. Mining interests had from the beginning blocked any development of storage capacity on the Waipori River itself. It was not possible to inundate Waipori Flat, which was still being actively mined, and an application to build a dam failed in 1913. After more than a year of investigations showed that the area was less rich in gold than had been believed, the Dunedin City Corporation Empowering Act of 1920 was successfully pushed through Parliament in the face of considerable mining opposition.

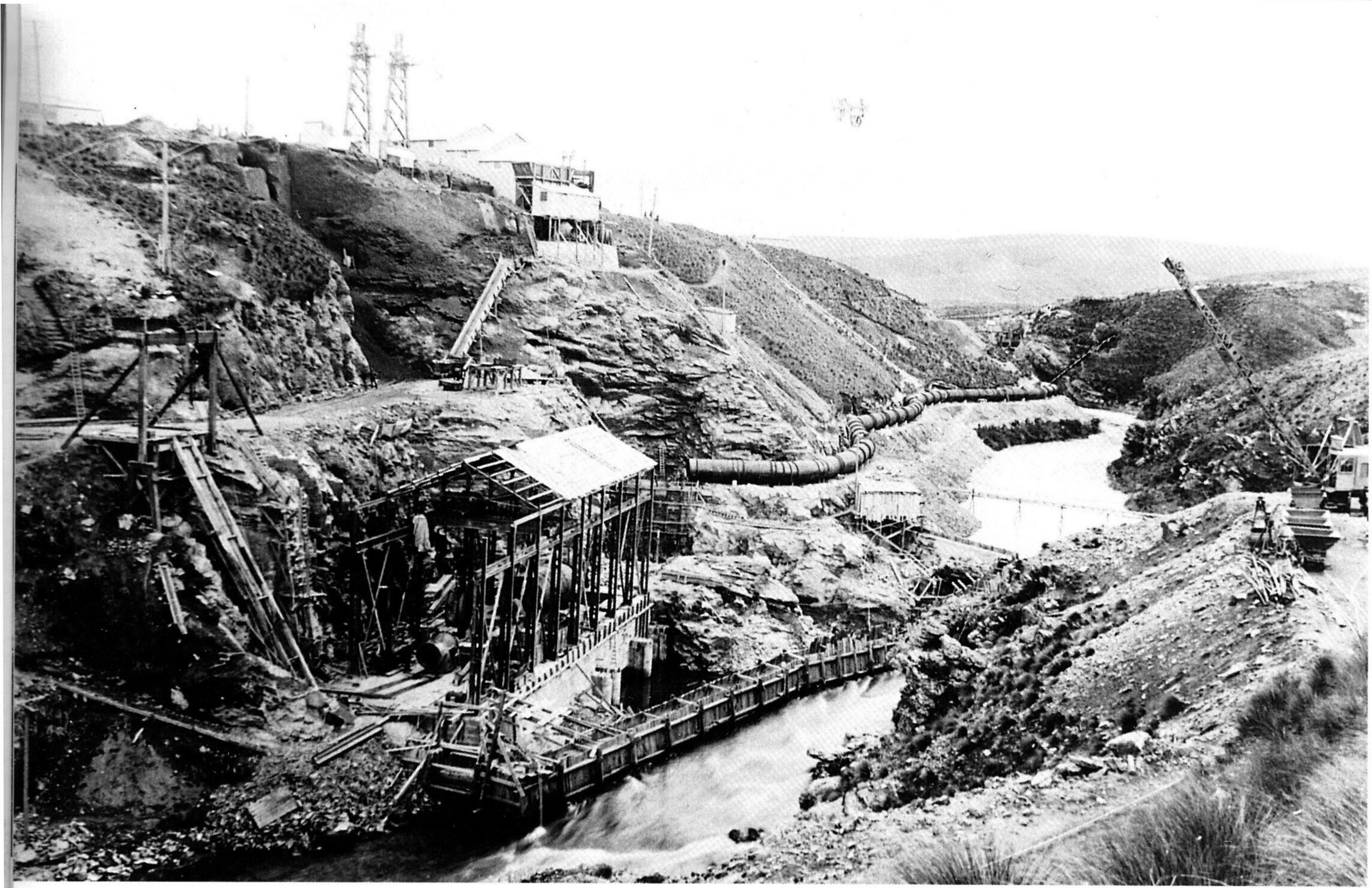
Right: The original Waipori power station, opened in 1907, had a long timber flume running down the gorge to the powerhouse. This was replaced by a tunnel after problems caused by sheep dislodging rocks onto it. These iron pipes being delivered to the powerhouse by bullock team, *c.* 1909, are probably associated with this reconstruction work.



Below: This photograph of the original Waipori power station shows the two Pelton wheels and 1,000 kW generators installed in 1907, which were joined by another four by 1913.

N. Rennie, *Power to the People*





Construction of the Waipori No. 1 power station, 1929. The powerhouse steelwork is going up, and turbine spiral casings are being installed. Preparation for the Mahinerangi dam, completed in 1931, can be seen, with a cut having been made for the abutment. It appears that, in the meantime, water for the No. 1 station is to be delivered from the dam upstream (built in 1923) by a steel pipeline, which can be seen snaking around the side of the gorge.

Bathgate photograph, Dunedin City Council

The Empowering Act released the Waipori River for storage purposes, but the city had to wait a long time before the full potential of the river was available. The first dam was built in 1923 and later raised. A further Empowering Act, of 1924, allowed a new dam to be built further downstream. After the original dam site had to be abandoned because of inadequate foundations, work commenced in 1927 on a new site downriver. By 1931 this dam was built to a height of 67 feet, forming Lake Mahinerangi and submerging the first dam. The Mahinerangi dam incorporated a powerhouse of 3,000 kW capacity (designated No. 1 station, with the old Waipori Falls station downstream now designated No. 2), which was the first remote-controlled station in the Southern Hemisphere, and only a few years after the first in the world. From 1935 Waipori was interconnected with the new Waitaki power scheme, after extended negotiations on whether to build another station on the river.

The Mahinerangi dam was completed to its final height of 110 feet in 1946, and in 1948, after equipment had been installed to feed Waipori power into the wider South Island system, approval was given for two more stations, 3 and 4, downstream from the old No. 2 station. Waipori, with its storage capacity, was to play a significant role in minimising South Island shortages and helping out in emergencies. The two new stations were built by 1954 and 1955 respectively, and helped combat the shortages prior to the commissioning of Roxburgh.

A new station, 2A, was built on the site of the original station. One 18 MW unit was commissioned in 1968, and two more of the same size were added, in 1975 and 1976. The original station was demolished in 1980, while in 1983 the No. 1 station at the base of the Mahinerangi dam was replaced by the 1A station of 10 MW.

CHAPTER TWO

Enter the Government

THE WAIPORI SCHEME provided the spur for government action. Developments up to that time had been at the initiative of private companies and local authorities, with central government's only role being the regulation of supply. By the turn of the century the government was beginning to look more closely at the possibility of becoming involved in electric-power generation by undertaking larger-scale hydro-electric projects. In the United States private enterprise had played a key role, while in Britain local municipal authorities had been crucial. In New Zealand the government became the key participant once it was decided that the generation of electricity could not be left in the hands of private enterprise.

This is understandable given the size of the country, its low population density and, from the 1870s onwards, the strong role the government had played in developing an economic infrastructure and controlling natural resources. The state was the only agency with the financial resources to carry out such functions. Intervention was also a feature of the 'state socialism' associated with the Liberal government of 1891–1912, whereby the central government acted in a strongly regulatory and paternalistic fashion on behalf of its citizens and various interests in a number of areas, including industrial relations, land and agriculture, pensions, housing and, as here, electricity. To some extent, the government's role also reflected considerable concern about the detrimental effects of private-enterprise monopolies.

The role of central government was to have significant long-term consequences, in that the development of electricity from the Liberal period until very recent years was not subject either to calculations of immediate profit or to local authority interest. This allowed a longer-term view of capital investment, and encouraged the development of a national system and of centralised planning and standardisation from an early date, while it also meant that electricity was extended into rural areas much sooner than in many other countries.

As early as the 1860s and 1870s the government had moved towards firm control of water rights. The Gold Fields Act 1866 introduced a new system of water rights. The Mines Act 1877 provided for the appointment of a Mining Registrar to license the construction of dams and water races, and the taking of water for use in all types of mining, driving machinery and irrigation. A licence could be issued only after the race had been mapped and an opportunity given for the lodging of objections. The Public Works Act 1882, which was largely concerned with water in gold-mining districts, put control over water supply into government hands. The government could declare any water supply to be a 'water-race', and thereby take charge of its use, whether it was in a mining district or not. The Mining Act 1886 and its amendment in 1891 further consolidated the government's control over water resources by ensuring that anyone wanting to dam or divert water had to obtain a licence to do so, and by limiting the issuing of licences when industries other than gold mining were involved. The 1891 Act also made it unlawful for local authorities to transfer or alienate their water rights. The clear implication was that the development of hydro-electric schemes was to be by central and local government rather than by private enterprise. When the potential for large-scale hydro-electric generation of electricity from central plants became apparent at the end of the century, matters came rapidly to a head.

The activities of J. C. Firth, the Auckland speculator and large estate-owner, in relation to the Waikato River, forced the government to take action. Having failed in 1887 to convince the Auckland City Council of the benefits of electric lighting, Firth lit his flour mill to enable it to be worked around the clock, only to lose both the mill and his Matamata estate when his creditors foreclosed in 1889. A man of restless energy, he turned his attention to the needs of mining and saw the potential of the Waikato River for electricity generation. He arranged for a survey by Professor George Forbes, who had been the chief consulting engineer and designer for the original Niagara Falls station, a landmark in hydro-electric development. Forbes' report selected the Huka Falls as a suitable site for a station. British financiers were apparently prepared to find £1 million if a long-term right to use the Waikato was granted. However, Firth was unable to convince the government that it should grant this, since it was argued that this would create a private monopoly akin to that exerted over the Niagara Falls.

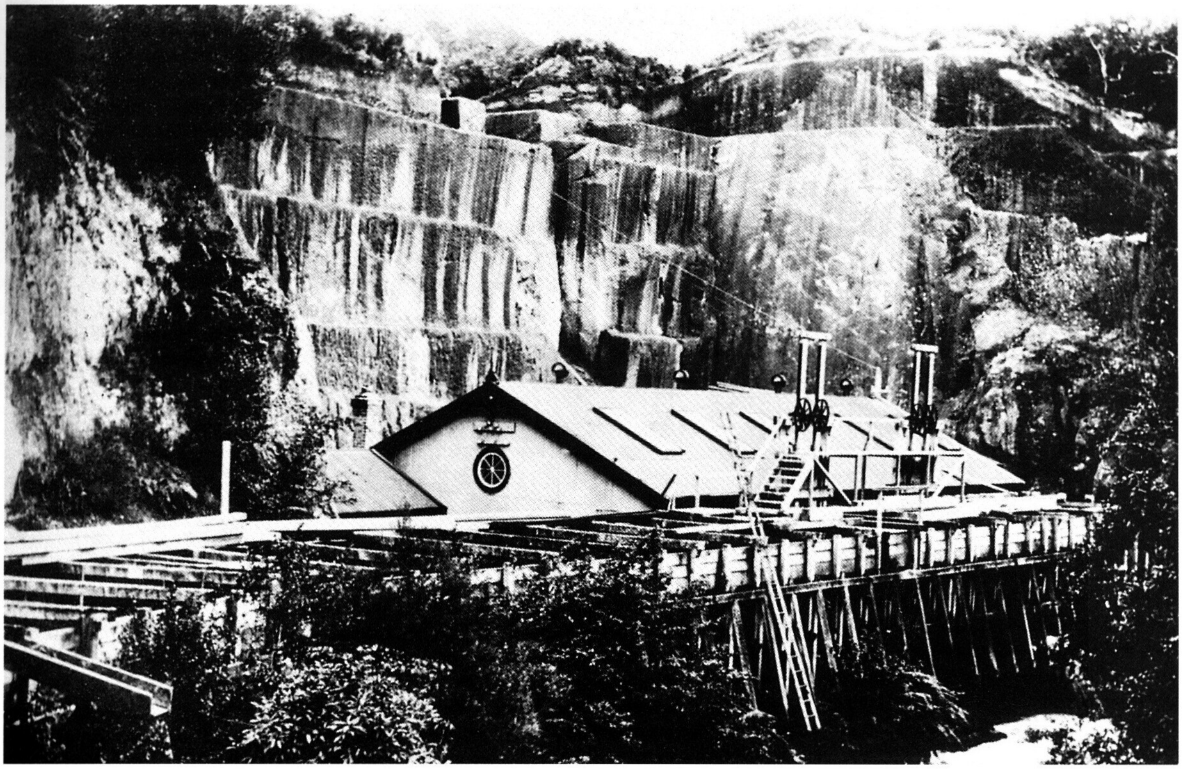
Seddon, who had once been a miner and was undoubtedly familiar with the crucial issue of water rights, acted rapidly to remove the possibility that this private development might be permitted by loopholes in existing Acts. With considerable haste he introduced the Electrical Motive-power Bill. In the Legislative Council, W. Downie Stewart, warning of the danger of North Island mines closing for lack of power, unsuccessfully moved an amendment that would have granted Firth the Waikato water rights. The short but extremely powerful Electrical Motive-power Act 1896 stipulated that any generation or use of electricity for motive power required permission from central government; no local authority could grant this right. This was a logical extension of the principle of government control established by previous legislation. In reaction to Firth's moves, the Act also authorised the government to make its own investigations into the feasibility of supplying electrical power to the goldfields using waterways.[1]

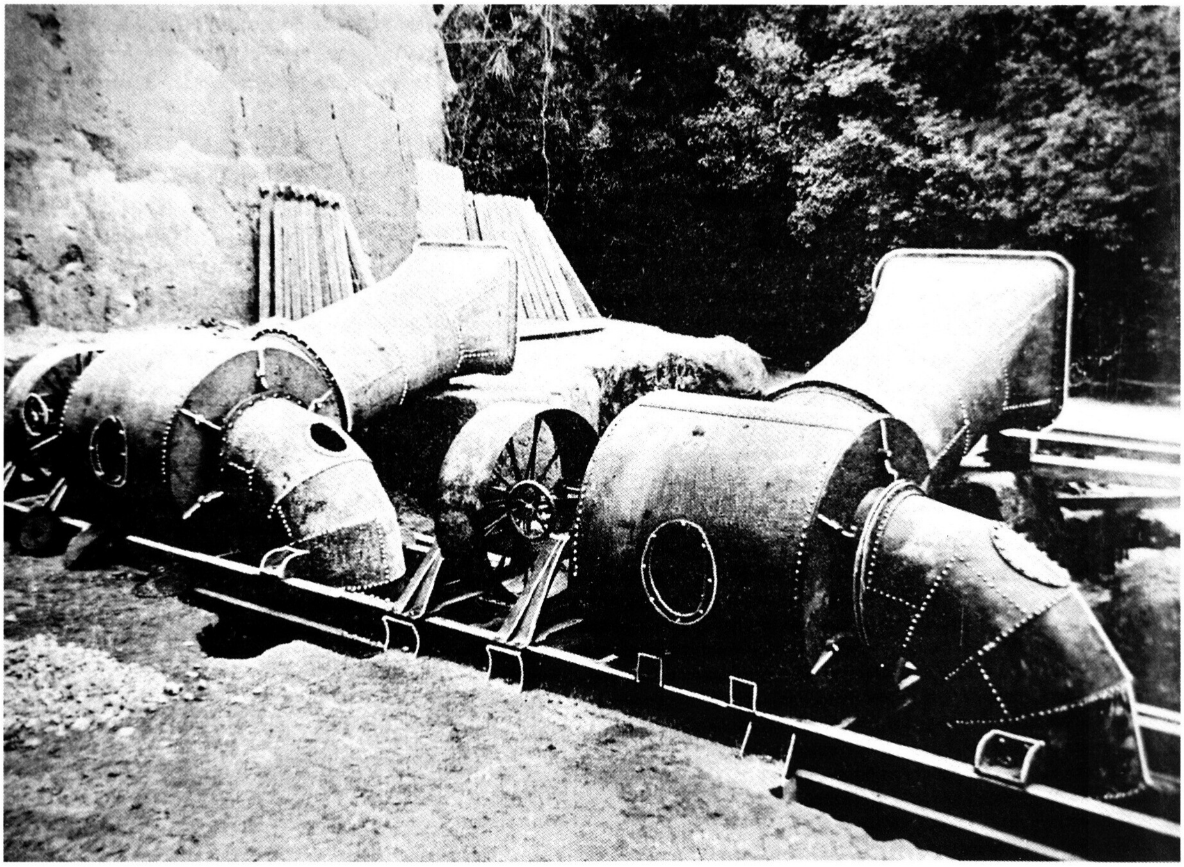
Little was done immediately, but in the early 1900s, with the support of the long-standing Minister of Public Works (1896–1908) and enthusiast for hydro-electricity, William Hall-Jones, Public Works Department officers collected a massive amount of hydrological data throughout the country. This information convinced the government to go further. In 1903 a Water-power Act was passed with almost unanimous support in both Houses. This specifically vested in the Crown the sole right to use water for generating electricity or to grant dispensations from this, thus signalling the government's intention to become a producer of electricity. Private enterprise was now completely excluded from public supply, except through local authorities. The example of Waipori bothered the government and led to it jealously guarding water assets. There a private company had obtained free water rights, which subsequently had to be purchased by the Dunedin City Council.

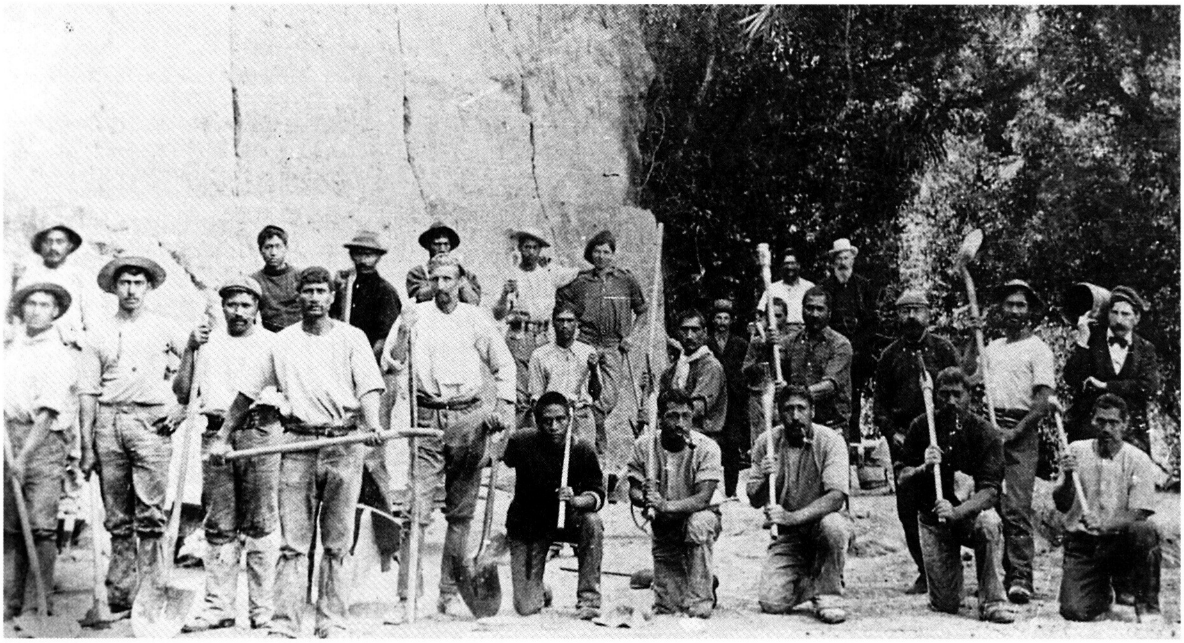
The government's first involvement with generation and distribution, other than the lighting of single buildings, came at the turn of the century in the tourist town of Rotorua, which was then controlled by the Lands and Survey Department.[2] Sewage works were required for the town, which had grown rapidly since the arrival of the railway in 1894. The government decided to generate electricity to drive the sewage pumps and for lighting. A contract was let to the Brush Company in 1899 to build a plant at Okere Falls, on the Kaituna River at the outlet from Lake Rotoiti. R. E. Fletcher was contracted to install the equipment. A 200-foot-long timber flume carried water from a dam to the powerhouse beneath the falls. Considerable excavation was required for the powerhouse, which was set into the base of the falls. The water dropped from a head of fourteen feet and drove two Waverley horizontal turbines linked to two 50 kW AC single-phase Mordey generators. The company erected a thirteen-mile-long transmission line to Rotorua and wired public buildings there, and the plant began operating in May 1901. The sewage pumps were driven by two 6 kW motors, and various public buildings and officials' houses, the railway station, the post office and streets were lit by incandescent lighting. Five thermal baths were lit by electricity,

Opposite above: The Okere Falls power station, on the Kaituna River at its outlet from Lake Rotoiti, was the first central government venture into electricity generation. It was constructed by 1901. Water was carried in a wooden flume from a dam above the falls down to the powerhouse at their base, where it drove two Waverley horizontal turbines linked to 50 kW AC single-phase Mordey generators.
Bath-house photographic collection, Rotorua Art and History Museum

Opposite below: This photograph shows the powerhouse site with the turbine casings in place, together with the pulleys for the belt drive to the generators which have not yet been installed.
AJHR, 1901, C-1







Some of the Okere Falls power station construction team, with shovels and pickaxes to the fore.

Bath-house photographic collection, Rotorua Art and History Museum

and a new bandstand, lit with eight incandescent lamps, was specially erected in the sanatorium grounds, which were themselves illuminated by nineteen arc lights.

This extensive electric lighting became almost as much of an attraction for the many visitors as the thermal activity itself. In less than a year there were nearly 800 connections, including two hotels, and within another year the plant was fully loaded, as domestic consumers quickly took advantage of the supply. The station was soon overloaded, and plans were made for extensions to it and for a spare generating set.

Lawrence Birks became Rotorua's Engineer-in-Charge in 1906. In 1907 a wing dam extending into the river increased the head and flow to some extent, and the total capacity of the existing units was raised to 95 kW. A second wing dam increased capacity to 105 kW in 1908, and another 100 kW generator was added at that time. The following year the system was converted to three-phase.

Horahora power arrived in 1926, but the Okere Falls plant still supplied a substantial proportion of Rotorua's needs. When the large Arapuni station on the Waikato River began generating, the local plant was used only for the evening peak period and for stand-by. With the closing of Arapuni for nearly two years in the period 1930–32, Okere Falls was run continuously, but it fell into disuse in 1936 and was dismantled in 1941.

Hay and Hancock

The year 1904 was a turning point in the government's interest in hydro-electric development. The general surveys on 'New Zealand Waterpowers' attached to the annual Public Works statement of that year formed the foundation for a national development plan. The total motive power produced in the country in 1904 (excluding the railway system) was 180,588 hp, of which 90.7 per cent was generated by steam, 5.5 per cent by water, 3.9 per cent by gas and oil, and a mere 0.3 per cent or 459 hp by electricity.[3]

Hall-Jones had invited L. M. Hancock, the Electrical Engineer and General Superintendent of the Transmission Department of the California Gas and Electric Company, to report on the hydro-electric potential of New Zealand's waterways. New Zealand and California both had high heads available, and power had to be transmitted over long distances. By this time the technology for long-distance 'point-to-point' AC transmission of electricity had been developed, and large-scale hydro-electric power plants were supplanting steam-driven plants. The focus of development of this technology at the turn of the century had been California, where the hydro-electric resources in the Sierra Nevada were hundreds of miles away from population centres. The California Gas and Electric Company was the public utility that monopolised these developments. Its pathbreaking project was the high-head Colgate plant on the Yuba River, which was commissioned in 1901. Three-phase 60 kV AC power was transmitted to Oakland, some 140 miles away — the greatest distance that electricity had been transmitted at that time.

Hancock visited New Zealand between October and December 1903, and was accompanied on his arduous journey around the country by P. S. Hay, the Superintending Engineer of the Public Works Department. They began at Wairua Falls in the north and finished at Lake Monowai in the south. Hancock's report considered 43 sites with a potential capacity for 2.2 million hp, much of it in the South Island, and made recommendations for possible initial projects, in particular Lake Coleridge.

Hay's more detailed report has become a classic. He looked in detail at more than 60 locations, and also at many other possible sites for development. He concluded that all possible schemes could produce a total of 3.7 million hp of hydraulic power and 2.2 million effective hp continuous working. If all other sources of energy then in use, including the railways, were to be replaced by electricity, some 250,000 effective hp would be needed, which would cost about £12 million. Hay concluded that 'there seems to be every reason to suppose that the gradual development of water-power would accelerate the general industrial progress of the colony by providing a supply of cheap power, much cheaper than steam or other motive power, and in a form to easily meet many varying conditions of service'.[5]

Peter Seton Hay was born in Glasgow in 1852.[4] He arrived in New Zealand in 1860 and graduated with the University of Otago's first BA in 1877, gaining an MA with first-class honours in mathematics the following year. He entered the Public Works Department as a cadet in 1875, and in 1879 was appointed as an Assistant Engineer in Dunedin. Moving to Wellington, he was promoted to Resident Engineer in 1886, Superintending Engineer for the country in 1896 and Engineer-in-Chief for the Department in 1906. His untimely death the following year was caused by pleurisy and pneumonia contracted after suffering exposure while inspecting the North Island Main Trunk railway line. Hay was a brilliant mathematician and civil engineer responsible for several outstanding constructions, including the design of significant railway viaducts and the selection of the route of the Otira tunnel. His thorough report in 1904 on the country's hydro-electric resources, which provided the basis for much subsequent development, has become a classic and is still referred to today. He died in Wellington on 19 March 1907.

The problem was the expenditure required at a time when Seddon refused to borrow more than £1 million per annum. Opposition to overseas borrowing, called 'self-reliance', was one of the strongest policies of the Liberal government. Seddon was also reportedly concerned about the impact of electrical generation upon 'his' West Coast coal miners.[6] In 1905 Edmund Allo, an electrical and hydraulic engineer, reported further, as a result of which some six projects — Huka Falls, Hutt River, Clarence River, Opihi River, Teviot River and Lake Hauroko — had more detailed investigations authorised for them. However, very little was in fact done over the following two years. Hay reported in 1906 on completed investigations, which favoured the Huka Falls, the Hutt River and Lake Coleridge projects.

The advent of Sir Joseph Ward's ministry after the death of Seddon in 1906 loosened borrowing policy, but public works expenditure was still monopolised by the railways. In 1907 P. S. Hay died and Hall-Jones fell seriously ill. The temporary Minister for Public Works, James McGowan, was a cautious man. In his annual report he opined that, as several million pounds were needed, a new public works policy (which the government was not yet willing to commit itself to), would be required. The Minister looked forward to the release of funds that would follow the completion of the North Island Main Trunk railway line.

Both the Water-power Act 1903 and the prior Electrical Motive-power Act 1896 were now incorporated in the Public Works Act 1908, which consolidated the control of hydro-electric development by both central and local government. Government policy was crystallised into a comprehensive legislative framework that ensured the state's key role. The explicit role of the Crown in the construction of stations, generation, and the supply and sale of electricity was stated formally for the first time.

The Public Works Amendment Act of the same year loosened this control slightly, in that its most important provision (section 5) allowed for the generation and supply of electricity by private companies, albeit under strict conditions. The government reserved the right to purchase any private plant at valuation. During debate on the bill, Hall-Jones indicated that the government would license 'water-power' for use by private enterprise, since it was not itself ready to start taking advantage of the resource. This concession followed some pressure to allow this much flexibility.[7]

The Waihi Gold-mining Company immediately applied to construct a large station at the Horahora Rapids on the Waikato River. This was the very kind of project the government had set itself against: a major private hydro-electric development.

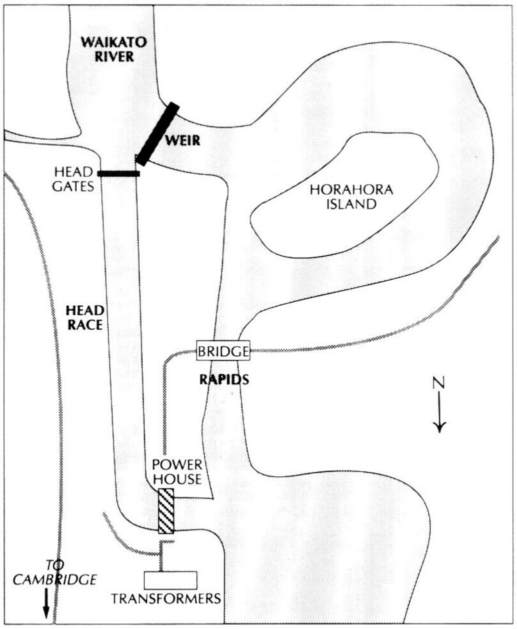
Horahora

Horahora was the first large-scale hydro-electric scheme in the North Island, the largest generating plant in the country at the time, and the first of the developments on the Waikato River that were later to be so important.[8] In the early 1900s the quality of the Waihi Gold-mining Company's ore was declining, and it began to consider using the Horahora Rapids as a source of cheap motive power to allow the crushing of low-grade ore. The government initially refused to grant a licence, but the company did not give up. After a long battle it was in 1910 given permission to construct a station developing up to 10,000 hp on payment of £1,200 per annum rental for water rights for 42 years.[9] The government had the right at any time to purchase the complete works at an agreed valuation.

At the Horahora site the river's course was diverted over two rapids by beds of rock. By cutting a large headrace across a bend in the river to bypass the rapids and building a cheap crib-work dam across the river, the company was able to create a reasonable head. Construction of the headrace, involved the removal of massive amounts of gravel and boulders, much of which was done by sluicing. By early 1911 a boulder groyne had been built to keep the river out of the headrace, and foundations for the concrete powerhouse were being prepared. In midyear the headgates were being built and the powerhouse had been started, and by the end of the year the powerhouse was going up rapidly and the tailrace was being excavated. The race was cut partly through soft rock which did not require lining, and partly through shingle, which was lined with concrete. This work was done during 1912.

During the bitter Waihi strike of May-November 1912 the 'Red Fed' unionists attempted unsuccessfully to get the Horahora construction workers out on strike. The company took advantage of the strike to electrify its operations further. The powerhouse was largely finished in 1912, and by October 1913 a groyne had been extended into the Waikato River to divert water into the headrace, and the station began generating electricity.

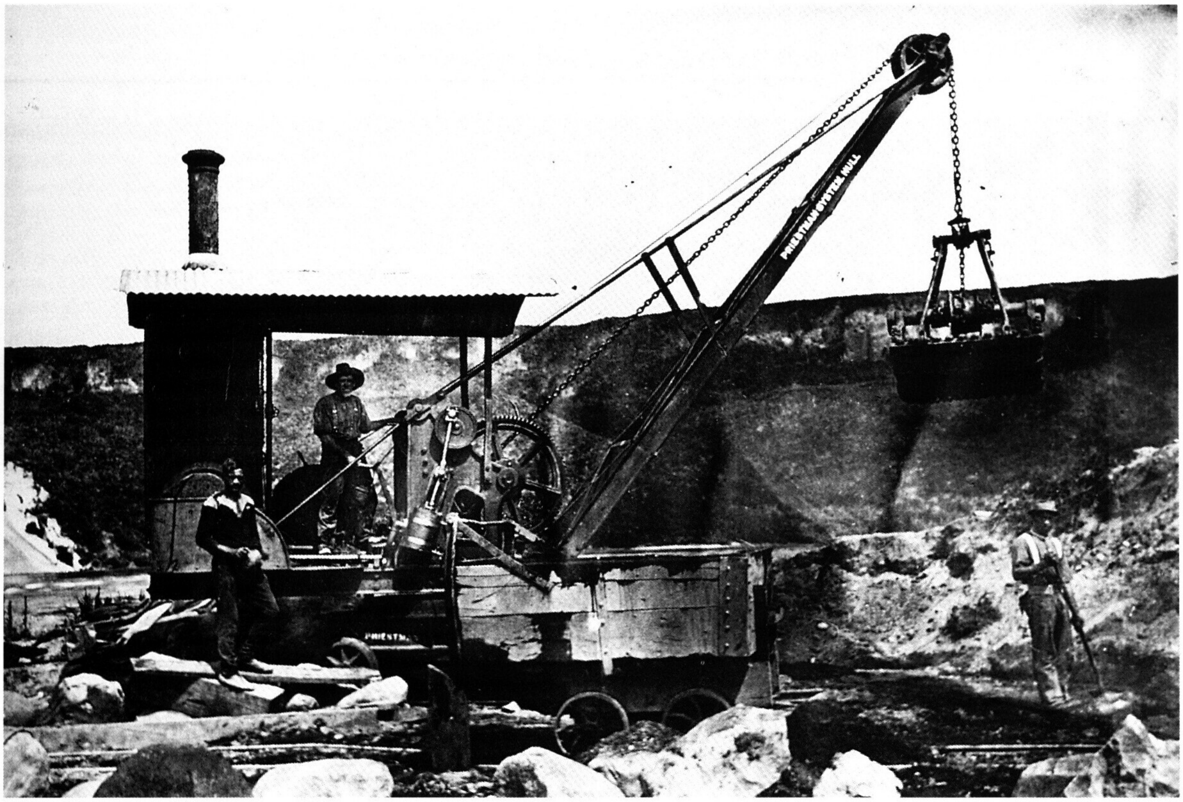
Horahora: Constructed 1910–13. Head 28 feet. A crib-work dam was put across the river, and water was directed into a 1,000-foot-long canal and to a reinforced-concrete powerhouse with six horizontal Francis turbines driving six 1,050 kW AC generators providing a total capacity of 6,300 kW. Some 45 miles of 50 kV line took the power across rugged, bushclad country to Waikino, where a substation stepped the electricity down to 11 kV for the five miles to Waihi itself. In 1919 the government purchased the station. In the period 1924–26 the headrace and tailrace were enlarged and the powerhouse extended. Another two 2,000 kW units were installed, making the capacity 10,300 kW. Horahora was submerged as Lake Karapiro filled in 1947.



With the completion of the scheme, virtually all the machinery in the stamping mills and mines was electrified. Horahora power drove 2,350 hp of electric motors at the mines, and lit 1,000 lights. Electricity was used for driving air com-

Opposite above: A steam-shovel excavating at the Horahora site.

Opposite below: Here the timber formwork for the draught tubes in the base of the Horahora powerhouse is being prepared for concreting.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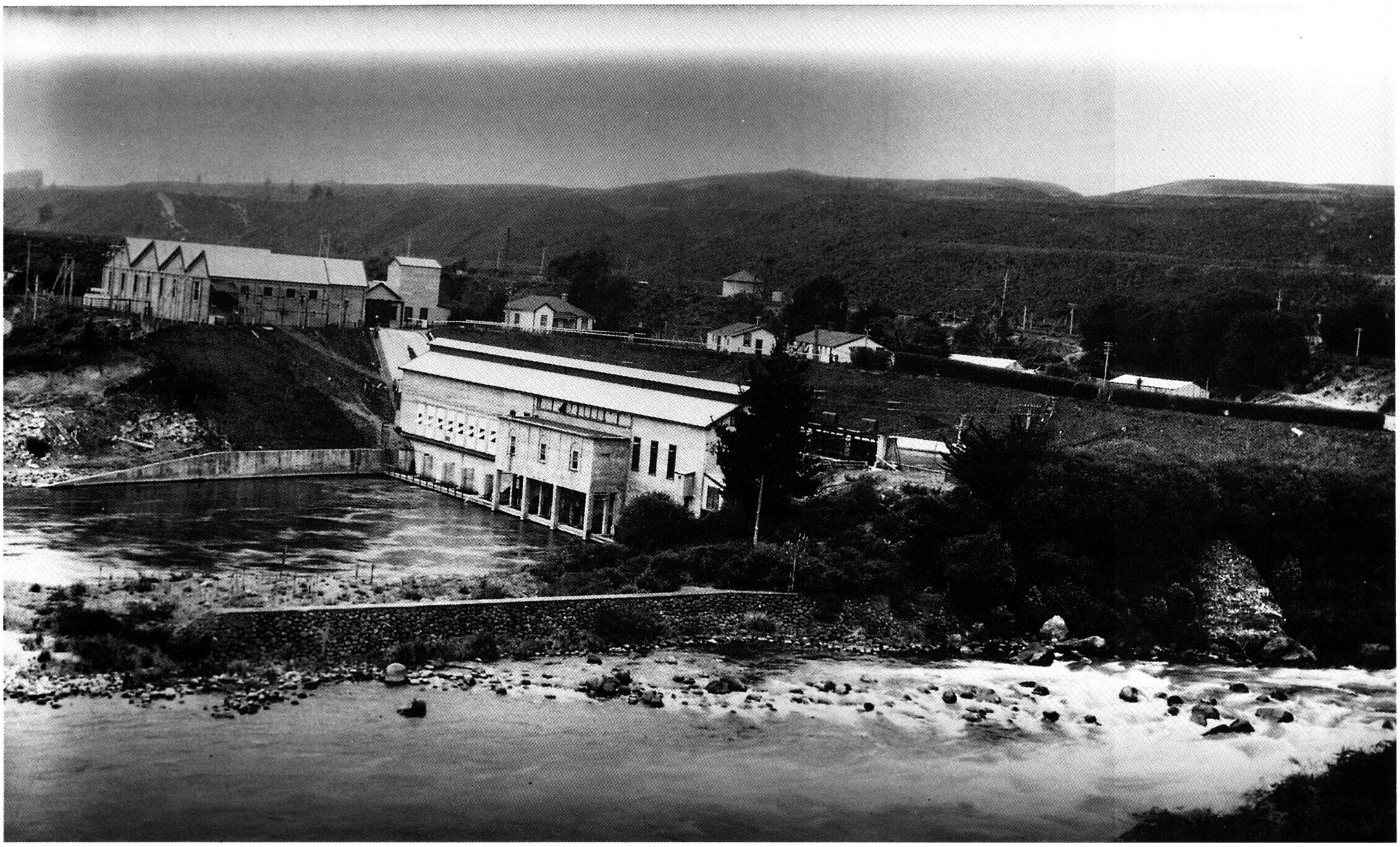
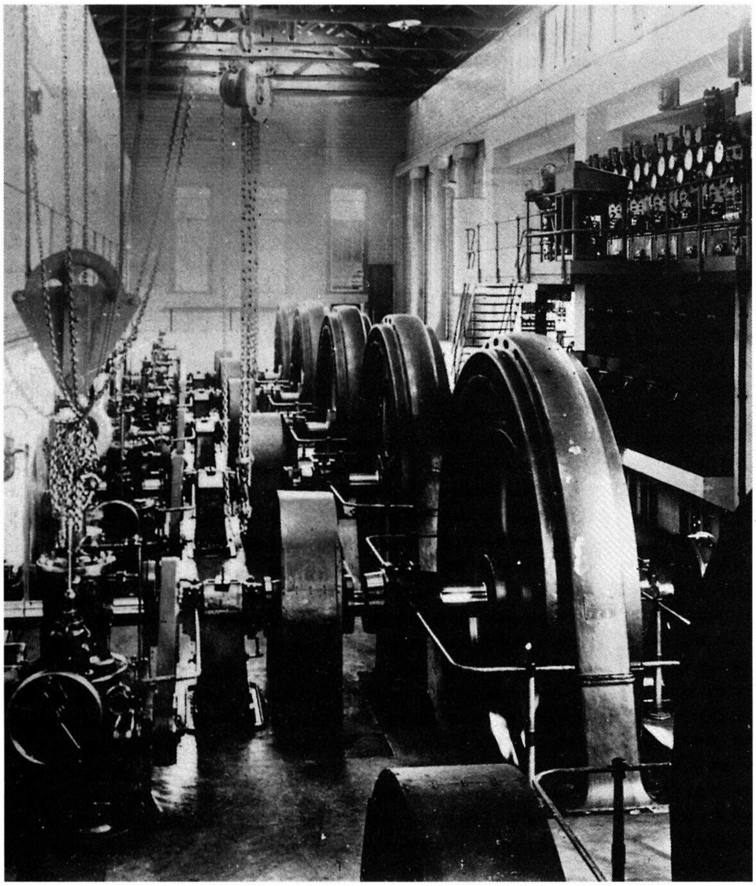




Above: Horahora station, the first development on the Waikato River, was the first large-scale hydro-electric scheme in the North Island and, at 6,300 kW, the largest generating plant in the country when it was completed in 1913. It was built by the Waihi Gold-mining Company on the Horahora Rapids (in the foreground) to power its huge stamping mills 50 miles away at Waihi. This *c.* 1926 photograph was taken after the government had purchased the station and extended its capacity to 10,300 kW.
AJHR, 1926, D-1

Left: The interior of the Horahora powerhouse, showing the row of six 1,050 kW generators, together with switchgear at right, in 1922.

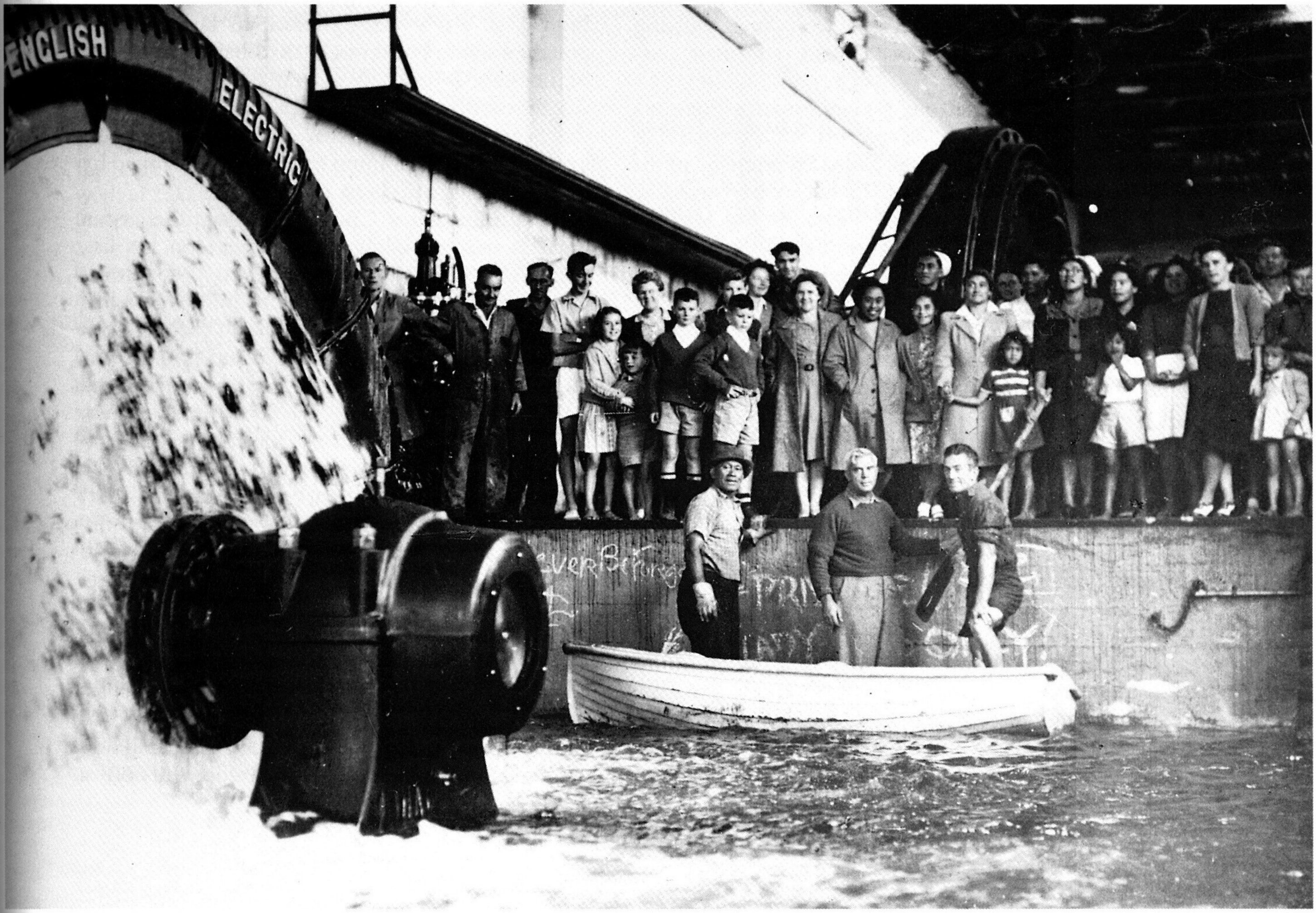
Opposite: In April 1947, when Lake Karapiro was formed, the Horahora power station — 'Old Faithful' — was submerged. While much of the equipment was removed, the turbines and generators were left in place and continued to turn as the water level rose, as shown here.

pressors, pump motors, hoisting gear, winding engines, fans, underground lighting, pumping stations and telephones, and for domestic supply to company houses. But because the power station was commissioned at a time when the ore reserves were becoming exhausted, the company never fully utilised Horahora's capacity.

In 1919 the government purchased the scheme, complete with lines, at valuation, the company retaining the right to take the power it needed. By this time it was being worked at only half capacity and the headworks had deteriorated considerably. By 1921 the station was supplying the towns of Cambridge and Hamilton and much of the rich dairy farming country of the Waikato and Thames Valley. By 1925 more than 1,000 milking machines and six dairy factories were supplied. In 1924 the government had begun the work of increasing the plant's output, an easy task since the available water had never been fully utilised. The headrace and tailrace were enlarged, the powerhouse was extended and another two units were installed. Transmission lines taking power to Auckland were built. This work was completed by 1926. Supply was now extended to Franklin County and Auckland, and before long (until Arapuni took over) to the Bay of Plenty and Rotorua. 'Old Faithful' Horahora continued to be relied upon for much of the north, and gave good and reliable service until the station was submerged as Lake Karapiro filled in 1947. The turbines contined to turn as the powerhouse filled with water.

Holmes and Birks

By 1910 the government's financial situation had improved. The North Island Main Trunk railway had been completed in 1908. Ward now began to move out of Seddon's shadow, initiating substantial overseas borrowing for public works schemes. By now demand for electricity had built up considerably, but little private initiative had been taken under the less restrictive 1908 Public Works Amendment Act. Urban populations were increasing rapidly, with the domestic use of electricity in particular rising quickly. The advent of the dairy industry and the introduction of electrical milking machines from the turn of the century added to rural demand considerably. In 1908



the Dairy Industry Act had established a system of herd testing and emphasised the necessity for cleanliness and ample supplies of hot water, which also increased the demand for electricity.

The 1910 annual report of the new Minister of Public Works, Roderick McKenzie, asserted that 'the time has now arrived to take up with vigour the question of developing our abundant water-powers'.[10] It was accompanied by reports by R. W. Holmes, Engineer-in-Chief of the Public Works Department, and by Lawrence Birks, who had been transferred from Rotorua to work on this new aspect of departmental activity. Holmes described the schemes under immediate consideration: Lake Coleridge for the South Island (which was linked with plans for railway electrification, particularly of the Christchurch–Lyttelton tunnel) and possibilities for eventual coverage of the North Island which included the Hutt River, the Kaituna River, Lakes Taupo and Waikaremoana, and Wairua Falls. He recommended that the government act as the wholesale supplier, selling power to large consumers such as city councils, drainage and tramways boards, and large industrial concerns beyond the range of local authority distribution lines. Holmes foresaw some difficulty in persuading authorities to scrap their existing generating plants, but considered their co-operation essential.

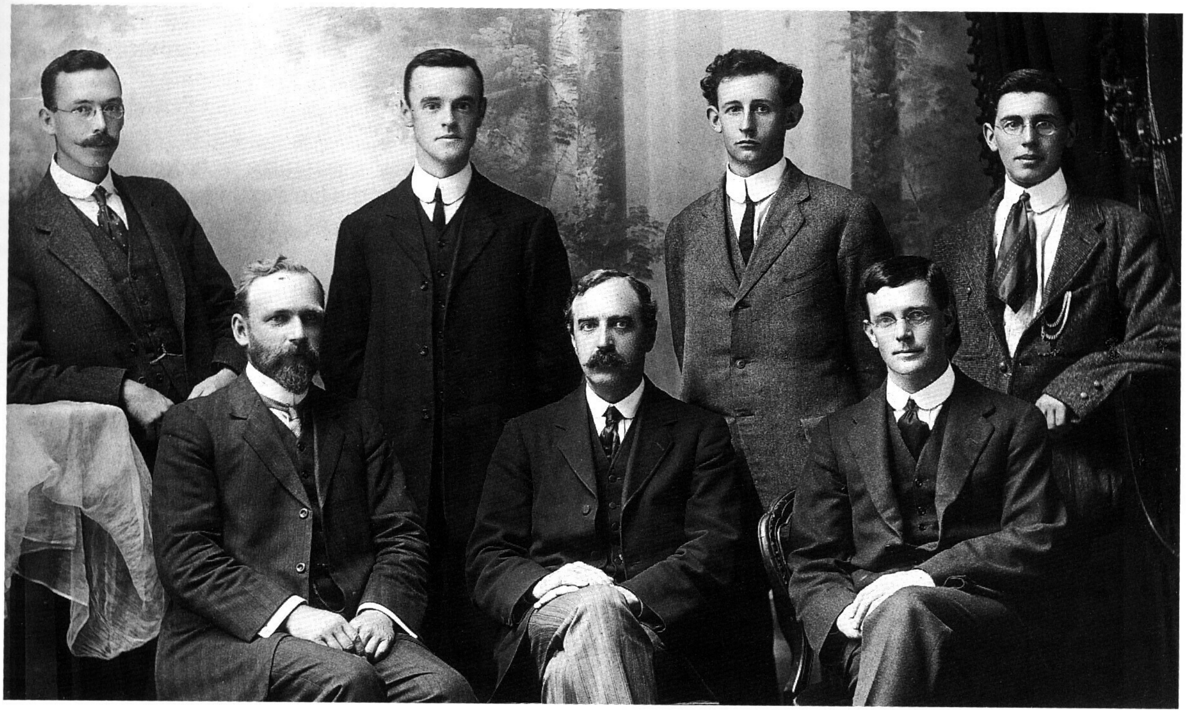
Birks' report set out a manifesto for the concerted development of the use of electricity in New Zealand. Almost all of his recommendations came to pass eventually. In his own words, he reported on 'the future demands for electric power in each of the centres of the Dominion, as influenced by . . . the possibility of obtaining a supply of power in large quantities and at cheap rates by the development of the natural resources of the Dominion . . . the popularizing of electricity as a general domestic agency, and the introduction of electrical appliances in the homes of the people for heating, cooking, and other purposes . . . the possible electrification of the suburban and ultimately of the main trunk railways . . . the establishment of special mechanical industries dependent on cheap power for their successful exploitation . . . the use of the surplus power for the manufacture of . . . [amongst other things] aluminium'.[11] He regarded hydro-electric development as the provision of a public utility rather than as primarily a source of revenue. Nevertheless, each project should yield sufficient profit to be self-supporting.

Birks surveyed the demand for various forms of power, noting an overall annual increase of about 2 per cent in the previous six years, with Christchurch's rate of increase being twice this and Wellington's nearly three times as great. The latter city, with its early adoption of electrical generation and efficient steam plant, led the way. In the four main centres tramways provided the single most important demand for electricity, but the electric lighting of households was expanding rapidly, particularly in Wellington, where more than a quarter were already supplied. Birks estimated that in the next five years, nearly 22,000 households would join the fewer than 6,000 throughout the country that currently were connected. He also estimated that the total horsepower of electric motors would double in the next five years. Birks noted that the use of electricity for domestic heating and cooking was beginning to be appreciated in Dunedin and Wellington, 'owing to the energy of the local authorities in popularising electrical appliances'. The lighting of streets by electricity had already been accomplished in Wellington and to some extent Dunedin, while Auckland and Christchurch still had little or no electric street lighting.

Birks considered suburban railway lines and the tunnels at Otira and Lyttelton to be important potential users, but thought that the electrification of the Main Trunk railway was a long way off. He suggested that electrochemical industries such as the production of nitrates and the smelting of iron, steel and aluminium might be encouraged by the availability of cheap power.

Birks argued that Christchurch was the city in greatest need. Wellington was next on his list, largely because of its closeness to a source of power in the Hutt River. Dunedin already had Waipori, which was 'an example of the excellent results that are possible'.[12] Auckland posed some difficulties, given the lack of nearby sources and the necessity for long-distance transmission lines. Birks described the Lake Coleridge scheme in some detail and recommended that it be proceeded with first, before discussing the Hutt River. Lake Coleridge could supply not only Christchurch but also its rural hinterland from Rangiora to Timaru. The situation in Christchurch was indeed critical. Its steam plants were overloaded and costly to operate, and the local authorities were unable to cope with demand.

McKenzie had prime ministerial approval to submit one or more schemes. A crucial step was now taken to ensure the continued financing and planning of hydro-electric development on a



Hydro-electric Branch, Head Office Engineering Staff, 1913.
Back row: H. M. Millar, E. Hitchcock, R. L. Gray, W. B. King. Front row: L. Birks, E. Parry, C. C. Butt.

The appointment of Evan Parry in 1911 marked the birth of the Hydro-electric Branch of the Public Works Department. Its engineering staff soon expanded to include Lawrence Birks and several others, as indicated in this photograph. At this time the branch was heavily involved with the construction work at Lake Coleridge, the first scheme to be built under its auspices.

national scale. The Aid to Water-power Works Act 1910 authorised the raising of £500,000 by the government for the construction of 'electric-power works', and the use of water for power generation. Ward, who had been impressed by a visit to Niagara, argued in his Financial Statement for the importance of taking advantage of water resources, which, unlike coal, were renewable. He suggested that up to £2.5 million might be expended over five years in the provision of some 60,000 hp.

The other important event of 1910 was the appointment, at a salary of £800 per annum, of the first Electrical Engineer in the Public Works Department, Evan Parry, who came with an impressive academic and work record. He was later to provide the plans that introduced a system of electricity generation, transmission and supply in this country (see Chapter Three). Many of these ideas were given initial shape in the first large-scale government project. Hancock had pointed towards Lake Coleridge in 1904. Parry now acted upon this option.

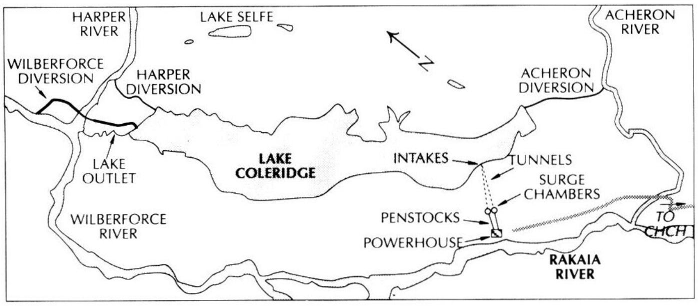
Lake Coleridge

This first major government hydro-electric project, while not initially the largest in the country, was of considerable importance in its signalling of the government's entry into electricity generation.[13] Lake Coleridge, some 65 miles inland from Christchurch and at an altitude of 1,667 feet, lies parallel to and nearly 500 feet above the Rakaia River, but less than two miles distant from it. Its natural outlet at its north-western end flows into the Harper River, just above its junction with the Wilberforce River.

The Lake Coleridge scheme was selected for a number of reasons. It was simple and cheap: water could be led directly down to a powerhouse, thereby creating a high head. The lake offered a large amount of storage without the need for costly dams or headworks, and would allow later extensions to the scheme. The power station would be relatively close to Christchurch, a major centre of consumption whose citizens had long been clamouring for power. However, the glacial geology posed considerable and novel problems.

Water would be drawn from near the south-

Lake Coleridge: Constructed 1911–14. Head 490 feet. The original 8-foot-high horseshoe-shaped tunnel of 6,952 feet took water from the lake to the surge chamber and into four (initially two) penstocks about 2,500 feet long. The initial penstocks bifurcated to supply four turbines in the powerhouse located beside the Rakaia River. The powerhouse is an early example of reinforced-concrete construction. The additional two penstocks each supply one further turbine. All turbines are of the horizontal Francis type. The original four turbines drive 1,500 kW generators. The first three were installed in 1914 and the fourth in 1917. Three-phase 50-cycle AC power was transmitted by two 66 kV lines some 65 miles to Addington substation, where it was stepped down to 11 kV. Two additional turbines driving 3,000 kW generators were installed in 1922 and 1923. In the later extensions a second 11-foot-high tunnel of 7,383 feet leads the water to another surge chamber and is connected with the old tunnel. Three further penstocks take the water to another three turbines driving 7,500 kW generators. Two units were installed in 1926 and the last in 1930. This brought the capacity of the station up to its present total of 34,500 kW.



eastern end of the lake down through a tunnel, surge chamber and pipeline to the powerhouse on the banks of the Rakaia River. In its natural state the lake's catchment area was quite small. Its main feeder, the Ryton River, had a flow of only about 50 cusecs, but it was recognised that the Harper and Acheron Rivers could be diverted, greatly increasing the catchment and allowing extensions to the station's capacity. The Wilberforce would bring in an even larger catchment, but that development was a long way off and would have to await the introduction of heavy earthmoving machinery. Hay's 1904 report had taken this wider catchment into account.

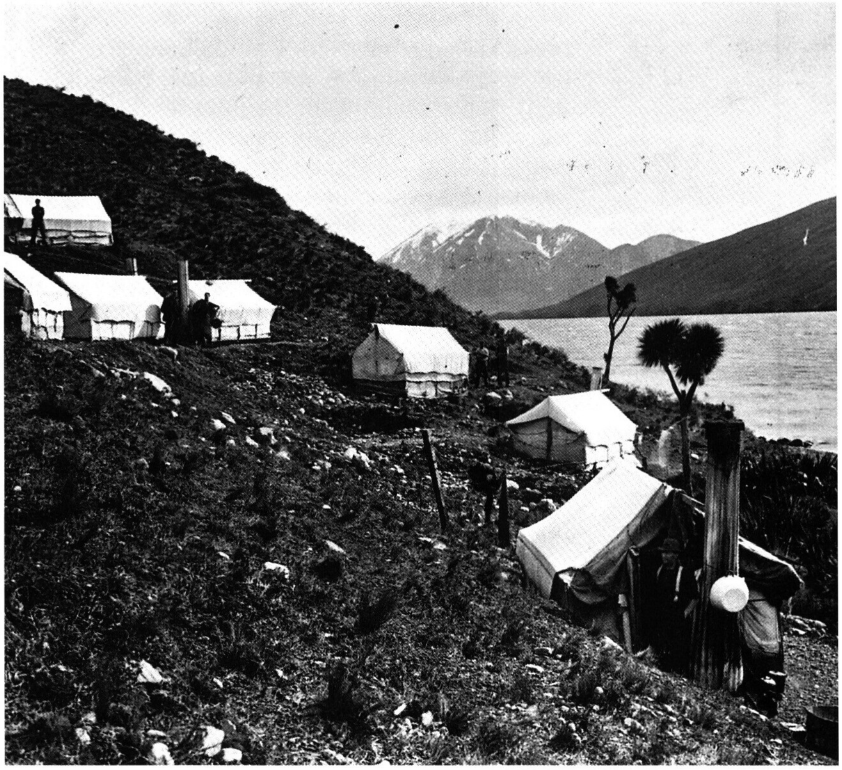
Staff were now assembled. F. T. M. Kissel, who had just investigated the scheme for the Christchurch City Council as Engineer for the Selwyn County Council, returned to the Public Works Department and was put in charge of survey and construction work in February 1911. Up to 400 men were involved in the project.

The Public Works Department was in charge of all work, and built the intake and outlet works and surge chamber, and excavated the penstock slope, foundations for the powerhouse, and the tailrace, as well as providing transport and installing the plant. The major job of the tunnel was driven under contract. Since the site had already been surveyed in some detail, work on the headworks began immediately after the decision to go ahead with the project in 1911. The workers at the intake lived in a group of tents and huts known as 'shanty town', set amidst bleak and windswept tussock country. They attempted without success to get a post office — a four-mile walk down to the Public Works camp was required to collect mail. Somewhat later a YMCA recreation room was established at one of the camps.

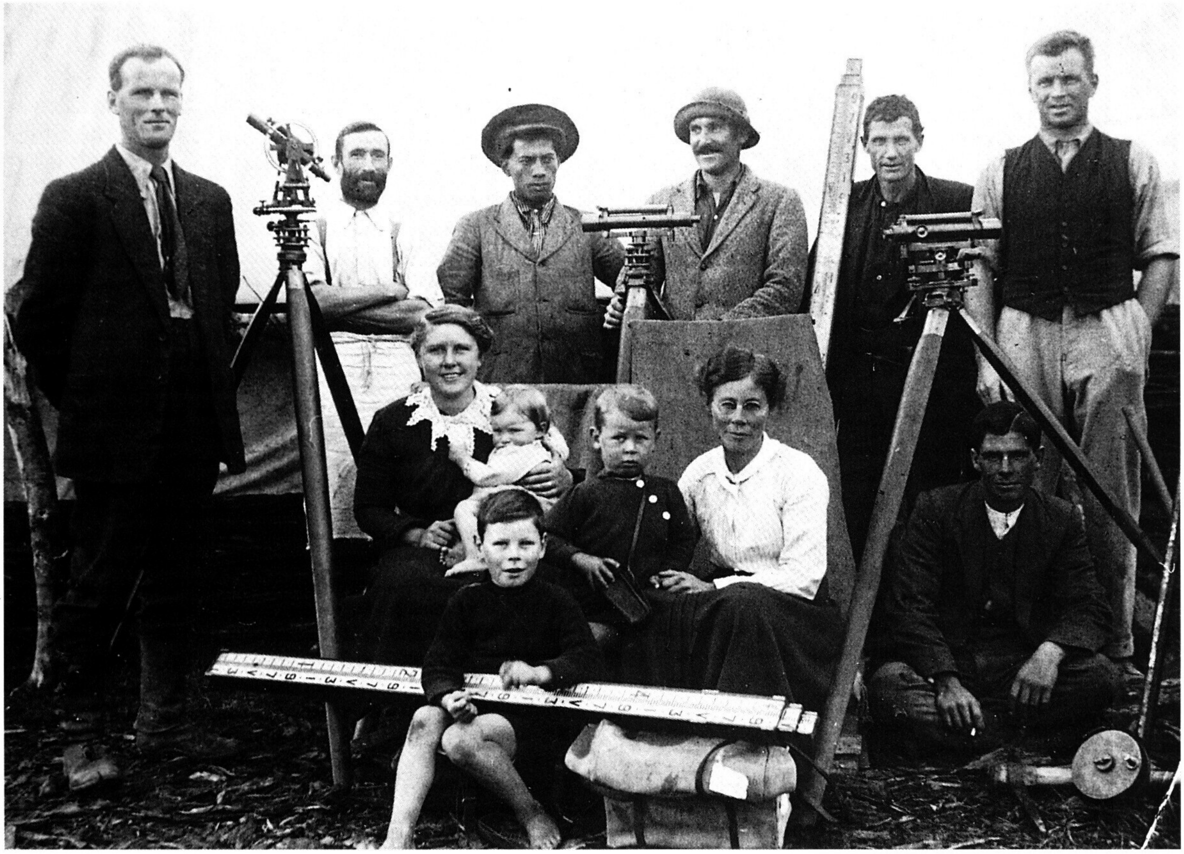
Access to the site was a major difficulty, so the road was extended to the powerhouse. Up to fifteen traction engines (nicknamed 'Furkert's motorcars' after F. W. Furkert, then a senior engineer in the department), Albion lorries and several horse-teams travelled to and from the railhead at Coalgate, 32 miles away. The traction engines proved impossible to use during the winter of 1912. The rough state of the road meant that only two trips could be made each week, and the lorries that carried lighter loads were falling to pieces. Horse-drawn vehicles were the most reliable, but also the slowest. In total some 12,000 tons of cement, machinery and other materials were transported to the site.

The major contract for the tunnel was let to J. McWilliams, who began work in 1912. A large number of contracts were let for equipment such as poles for the transmission lines, insulators, transformers, generators and turbines, and for the construction of the powerhouse building and the first two penstocks.

A description of earthmoving techniques of the time gives some impression of just how labour-intensive construction methods were.[14] The pick, shovel and wheelbarrow ruled, supplemented by horse-drawn drays and carts. There was virtually no powered plant other than some steam excavators. Concrete was mixed by hand. Excavation



Right: Camp at Lake Coleridge for workers constructing the intake, 1913.



Below: G.P. Anderson at right, standing, with his wife centre (holding the baby), chainmen and members of their families at an encampment, Waikaremoana. A theodolite, levels, staff and a chain are displayed prominently. Surveying was a vital part of preparatory investigations for the construction of power stations and the building of transmission lines. Survey parties shifted from camp to camp, living under canvas and largely off the land.

was also undertaken by hand, or by horse-drawn plough-and-scoop where stumps and roots did not pose difficulties. Drilling for blasting was done with hand augers or 'jumper' drill rods in soft rock and manually operated hammers and drills in hard rock. The gelignite used was dangerous at low temperatures. Excavated material was transported by horse-drawn end-tipping carts or scoops running on light steel rails.

The Lake Coleridge tunnel was driven by hand with the aid of compressed-air drills, largely through compacted moraine shingle. Material was loaded by hand into carts and pushed manually, or when possible, hauled by horses. Shingle was shifted at the lake and from the Rakaia River by means of a tramline and a petrol engine.

The Public Works part of the project went well, but McWilliams proved to be thoroughly unsatisfactory in both work methods and safety standards, as well as in housing and feeding the men he employed.[15] By July 1912 some progress was being made, but work at the tunnel outlet was made difficult by several slips caused by the lack of timbering. The shaft in the middle of the tunnel had reached bottom, and work had begun on the drive towards the outlet end. At the lake end of the tunnel progress was slow, blasting being necessary. Dissatisfaction surfaced at this time, with tunnellers reporting the worst conditions they had ever worked in. They alleged that despite the dangerous conditions, with loose and shifting material, the timbering was not kept up to the face. Less than one-fifth of the tunnel had been driven and the lining had not been started.

In August 1912 some 32 workers at Coleridge founded a branch of the Canterbury General Labourers' Union — a very active industrial union then at its peak. They protested to the Minister of Public Works about having to eat at McWilliams' own canteen, where they were charged 18s a week for food which was hardly fit to eat, 'consisting chiefly of mutton cooked in different ways and potatoes'. They also complained about the unsafe work practices, particularly the fact that uncertificated engine drivers lowered them 200 feet down the improperly lined shaft to the tunnel face. The state of the engine boiler, and a malfunctioning braking clutch caused concern. The inadequate clutch resulted in the cage falling 100 feet and smashing. The subsequent dismissal of the engine driver provoked a strike amongst the men in September. They also struck over the refusal of two carpenters to join their union rather than the Carpenters' Union, and over other issues such as extra pay for overtime and double pay on Sundays and the fixing of a ladder in the shaft so that the men could get out. Two constables were sent to the area to ensure order.

In the same month questions were asked in the House of Representatives, and the Minister demanded a report on the work. Parry's report recorded that McWilliams' organisation had collapsed entirely and recommended that the Public Works Department take over. McWilliams had run out of coal to work his engines, and timber for tunnel supports. Affairs were very unsatisfactory: tunnels were being worked in a dangerous manner; the shaft engine had been replaced by a newer and larger one, but its winding wheel was bound on with wire; ventilation in the shafts was bad; the gelignite store was close to the works; baths and changing rooms were not available for the men; and the cooking was bad.

Men were leaving in droves. Some of these problems were soon dealt with: a butcher, baker and grocer began regular visits to the camp so that the men could purchase and cook their own food; the shaft lining was improved; and the boiler, which was too small, was replaced.

Further trouble arose in January 1913, work on the tunnel all but ceased, and most of the men left for Christchurch. Birks now came to take charge of matters. By December of that year it was clear that the contractor could not complete the work on schedule. Supply to the Christchurch City Council was supposed to start on 1 May 1914. In February 1914 the contract was cancelled and the work was taken over by the Public Works Department under Kissel's supervision.

The delays made the May 1914 target impossible, so a temporary supply from the tramways board was arranged for the high winter demand. By May the lake end of the tunnel was within eight feet of the nearly complete concrete intake and control gates. The tunnel had been concreted and was now being plastered. That month the site was inspected by Birks, the mayor of Christchurch and others. One newspaper reporter at this time drew a graphic picture of the vision of Coleridge:

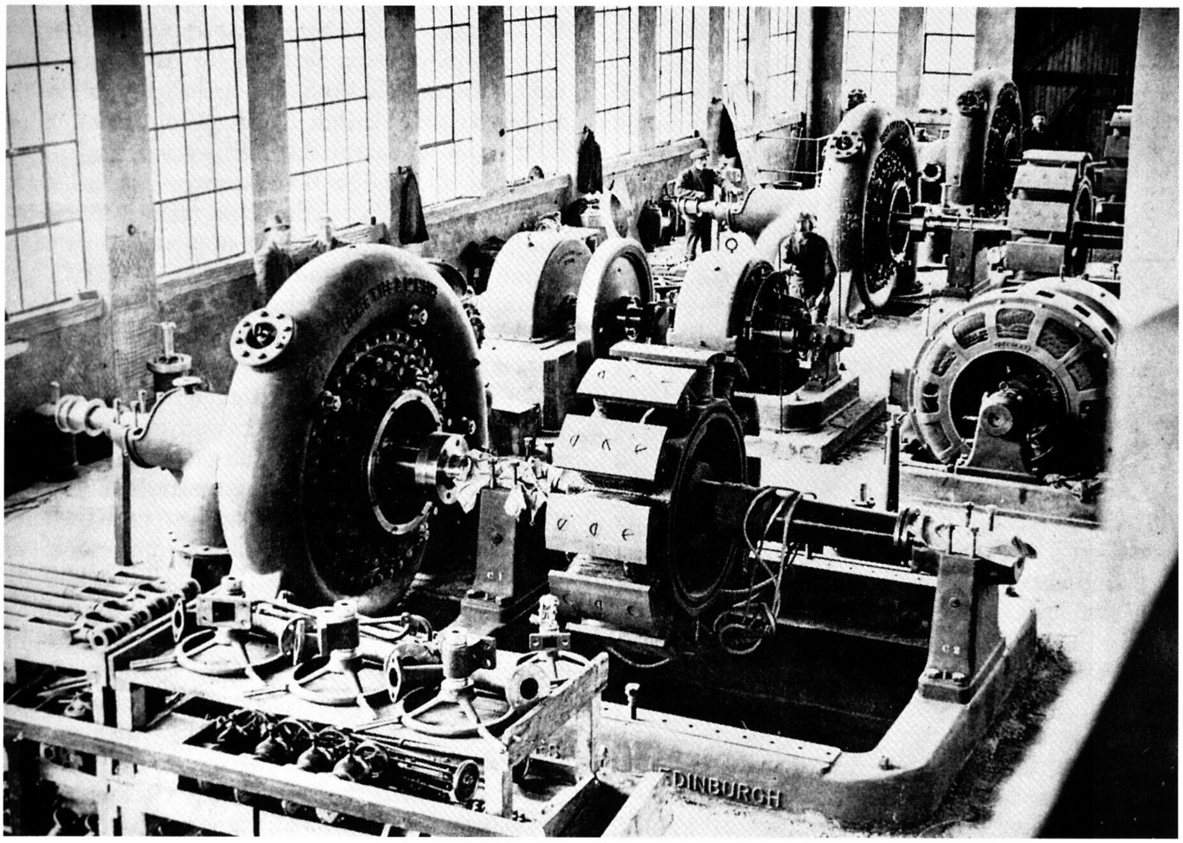
> The dream which an engineer dreamed a decade ago as he stood amongst a circle of towering hills and looked at the scintillating surface of a wind-flecked lake is coming closer and closer to realisation. In his mind's eye he saw the latent power of that lake harnessed and developed; he saw a city eighty miles away

> illuminated by its power — homes twinkling cheerily through the gathering dusk, and factories whirring vigorously through the daylight hours. And he made elaborate drawings and extensive computations, and he sent forth men with line and chain and theodolite to gather data for the fabric of his dream.[16]

The end of the tunnel being driven under the lake struck major inflows of water in June 1914 and was shortened because of the danger of the thin rock ceiling collapsing. By August the tunnel had been completed and filled with water and the penstock pipes had been tested successfully at working pressure. The powerhouse structure, built on glacial moraine and the largest of its time in the country constructed solely from reinforced concrete, was begun in 1913 and finished by June 1914. The switchboard and the first three machines were then installed and the tailrace flumes finished. E. H. Hitchcock, who was involved in the powerhouse design, 'lived-in' while preparing the big 25-ton turbines. Problems with 'water hammer' led to the novel development of 'aerated' draft tubes, which were subsequently adopted as standard on turbines the world over. Transmission to Christchurch was by two lines 65 miles long and carrying 66 kV, the longest line and highest voltage used thus far in New Zealand.

Nowhere else in the world had a scheme been constructed in what was in effect a vast bottomless moraine. There were problems in the area of the intake, tunnel, surge chamber and penstocks. Mistakes made in the powerhouse foundations made alignment of machines very difficult until grouting provided stability. Measures taken to solve these difficulties were often experimental but usually successful. Engineers who now service the Coleridge machines speak of them as temperamental creatures requiring individual understanding. That these machines are still working attests to the skill and pride with which they have been tended for more than 75 years.

Lake Coleridge was officially opened by the Prime Minister, William Massey, in pouring rain on 25 November 1914. The station required



The installation of three main turbines and generators in the Lake Coleridge powerhouse. While the turbines have been completed, the generator stators are still to be installed, leaving the rotors exposed.
AJHR, 1914, D-1

The completed Lake Coleridge powerhouse, with the Rakaia River in the background.
Alexander Turnbull Library

between 60 and 80 people to operate and maintain it. Continuous electricity supply was not available until all the headworks were finished. Parry was not pleased about this delay and sent a sharp memorandum to Birks. He was impatient of explanations offered for delays in clearing the intake. The department was suffering considerable financial loss, 'and every member of the staff must share the discredit'. Birks must have been glad to write on 3 March 1915 that 'we went straight into 24-hour service on Monday morning'.

From the start the government was determined that Coleridge would be economically viable. Parry wrote: 'there is the . . . point of view that the development of water-power . . . helps to develop the country, which is a justifiable end in itself; but I have not, however, taken advantage of this aspect of the case, but endeavoured to conduct the [Lake Coleridge] development on strictly economical lines.'[17]

Complicated negotiations with the Christchurch City Council on the terms of supply had begun in 1911. It was absolutely crucial for the project's viability that a large bulk consumer be secured. A report by F. Black, a Wellington electrical engineer, in December 1912 suggested that if the council provided its own gas, steam or oil plant the production cost would be twice that of Lake Coleridge electricity. A ratepayers' poll on the matter held in February 1913 agreed to the report's proposal that a substantial loan be raised for reticulation and installation in the city, and the government reached agreement with the council later that year. A contract was signed under which the council would take a minimum of 500 kW and the department guaranteed to supply up to 4,500 kW. Prices were to be fixed for five years. This agreement established the principle of local-authority reticulation and retail distribution of bulk supply from the state. This was articulated in the Lake Coleridge Water-power Act of 1915, which gave local authorities taking electricity from the scheme powers to supply electricity and to raise loans to do so.

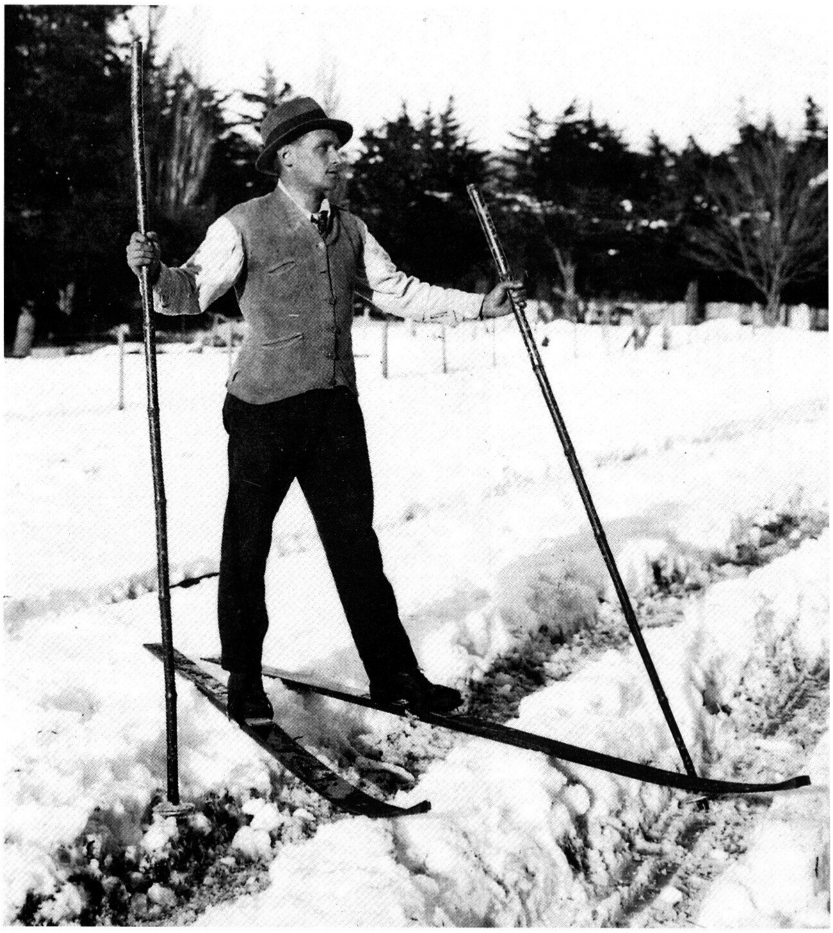
Local bodies adjacent to the city debated whether to take their supply direct from the government or through the city council, which had a contract designed to encourage consumption and looked to a larger load to reduce unit costs. The council sent a delegation to the Minister of Public Works, who assured them that the government was not in competition with the city, but nevertheless emphasised the importance of this pioneer scheme being financially viable. By June 1914 the department had begun negotiating with the Lyttelton Borough Council and Harbour Board, while the Christchurch Electricity Committee met with other local authorities to discuss the terms for supply. By March 1915 ten bulk consumers were contracted and more were in prospect. The Tai Tapu Dairy Company was organising reticulation in its area and had constructed fifteen miles of line by September 1915.

The 1915 Public Works annual report stated that Lake Coleridge was both an engineering and a financial success. At first demand had not increased rapidly, but once various contracts of supply were successfully negotiated, load began to rise quickly. As well as the Christchurch City Council, the tramway board and the harbour board, three counties, eight other local authorities, three freezing works, two tanneries, two dairy companies, two flour mills, and six other institutions were being supplied within a year of the scheme opening. Birks launched a publicity campaign that included visits to Timaru, Temuka and Geraldine, although these areas were not in fact to get Coleridge power for some years. Reticulation did not reach Timaru until 1923. Within two years peak demand began to exceed supply. This was the first sign of what was to be a familiar pattern in all early projects: the initial supply of electricity generated new demands, which then quickly outstripped supply.

The plant proved efficient and reliable, and enabled an immediate and dramatic reduction in electricity charges to consumers. Previously between 3½d and 6d a unit had been charged for lighting and 2¼d to 3d a unit for motive power. Now electricity was available at about half these rates.

The supply failed several times in the first few years because of the unreliability of the cheap pin insulators. Just before 8 p.m on 20 April 1915 Christchurch was plunged into darkness when a thunderstorm broke down insulation on the line. 'Theatres, hotels, halls, the General Post Office, the Telegraph Office, the Police Station, and many other places which usually are bathed in bright electric light, were affected.'[18] At the Theatre Royal the performance continued with the aid of limelights, while at the Queen's Theatre the orchestra played for an hour and a half without a break until the power came on again. The backup refuse-destructor plant was activated as quickly as possible, and some power was made available by 9.30 p.m. Power from Lake Coleridge was not restored until the following morning.

In the early morning of 30 April 1917 broken insulators on both lines caused the loss of power for about an hour until the tramways and destructor plants could be brought into action. On 1 July 1918 massive snowstorms caused a complete breakdown of supply for several days by bringing down the lines more than once. All communication with Lake Coleridge was lost, and it was impossible to proceed beyond Hororata by vehicle. Power could not be restored until there was communication. Boris Daniel of the Public Works Department in Christchurch, and originally from Russia, volunteered to try to get to the powerhouse on a pair of skis used by Captain Scott on his 1912 Antarctic expedition and kept at the Canterbury Museum. His mission was successful, communication was re-established using one of the power lines, and the electricity supply was reinstated.



The massive snowstorms of July 1918 caused a breakdown of supply for several days, and prevented anyone reaching the Lake Coleridge station. Boris Daniel, depicted here, managed to get there on skis and iron-shod bamboo poles borrowed from the Canterbury Museum and originally used by Captain Scott on his 1912 Antarctic expedition. He had to promise not to damage either the skis or the poles, and as a result skied in an unnatural posture with his arms held out stiffly from his body. After staying overnight at the station, he arrived back at Hororata exhausted.

By the time the fourth machine was installed in 1917 the full capacity of the plant was required to meet a demand whose nature had changed within those few years. At first lighting provided an early-evening peak, but with the conversion of larger factories to electricity this was supplemented by morning and afternoon peaks. In the morning demand rose rapidly from 6.30 a.m. as the trams moved out of their sheds, and from 7 to 8 a.m. as factories and then shops began operating. At noon demand declined as lunch-time was taken. By 1 p.m. load was restored, with a peak reached between 4 and 5 p.m. in winter as factories, shops and offices switched on lighting. From that time onwards there was a gradual decline in load into the evening, with a small peak between 7 and 8 p.m. for the evening meal. The residual demand throughout the night was largely for street lighting.

The rhythms of demand became the signature of the life of the city. As one reporter visualised it,

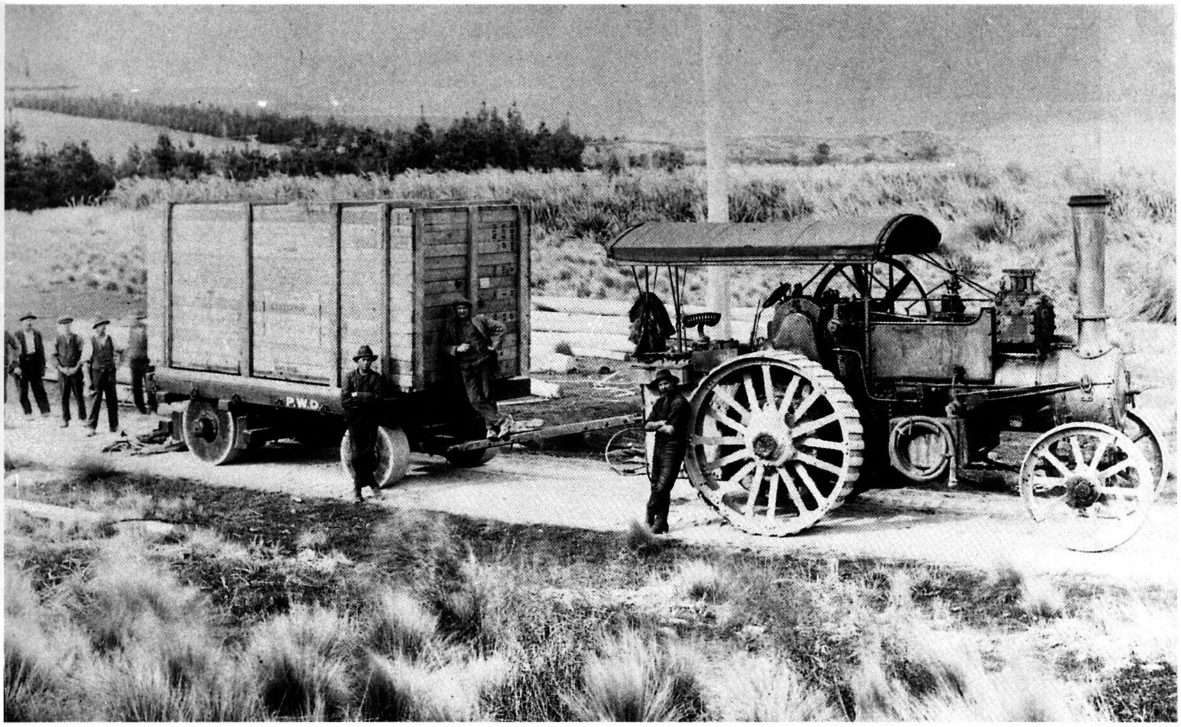
> just as vigilant as an officer on the bridge of an ocean liner, an officer of the city's electrical department patrols the switchboard of the city's lonely power-house, sixty miles away, under the gathering snows of the Mount Hutt Ranges. His turbines sing an endless song as the snow waters of the lake fly through the blades to join the roaring Rakaia River below. It may be Sunday night. The sentinel notes the lighting up of the city homes, as a greater effort is asked of his flying turbines. Presently, he notes the church hour, as a tell-tale dial hand moves lazily at lighting up time. He sees the hand go lazily back as a hundred vergers switch off the church lights. He notes the social hour that follows the home-coming, and his thoughts may fly to some envied supper circle in the city. The townsfolk yawn, and go to bed. A little tell-tale records the fact up in the mountains.[19]

The tramways plant continued to be a useful emergency supply, capable of running its own vehicles and putting 1,000 kW into the Addington substation for essential consumers. The Christchurch City Council continued to be the largest customer, and had indeed managed to reduce retail charges to consumers further. By 1920 the scheme's annual revenue was greater than the sum of working expenses, depreciation and interest.

The history of Coleridge from this time until the Waitaki scheme was commissioned and linked in the mid-1930s was one of demand leap-frogging extensions to the plant. In the 1920s attention was turned to the question of increasing the flow into the lake in order to run additional capacity. The Harper River, with an average of 500 cusecs of water flow, was the most important potential source. Early in 1920 the level of the lake became dangerously low after a severe drought. Coleridge was by now working at a considerable overload, with connected load having increased by one-third in a single year. New customers were being strongly discouraged.

The Harper was eventually diverted in March 1921, after a 102-chain channel to the lake's north-western end was cut by horse-drawn scoops. The level of Lake Coleridge was restored somewhat, but freshes in the river broke through the dam and the engineer considered that the Harper River might well return to its old course in a heavy flood. More permanent diversion works were necessary. Before this work could begin, the river washed away the temporary diversion and cut itself an entirely new channel at the western bank in July. Work on a new and permanent diversion further upstream began three months later. But the Harper was not to be tamed easily. In April 1922 it flooded once more and washed away most of the new dam, while in July it cut through the embankment. It was September 1922 before the groyne embankment was complete, and February 1923 before all work was finished. The Harper now became the lake's major contributor. Other work completed at this time involved gates to control water flowing into the lake and a new concrete dam at the outlet to raise its level slightly. After this dam failed in 1926, its replacement raised the lake a little further.

A fifth machine of 3,000 kW had been ordered during the First World War, but steel for the penstock was unobtainable at that time. The plant's capacity was eventually increased to 9,000 kW by its addition in March 1922, but the station was almost immediately overloaded. Another unit of the same size was added in January 1923, but the plant became overloaded again little more than a year later. The heavy equipment for the extensions was carried in on a massive specially built wooden-wheeled trailer that had a capacity of more than twenty tons and was towed by a traction engine. The trailer was subsequently transferred to the North Island, where it gave good service until 1939, being used in the 1920s to transport equipment into Mangahao and then Tuai.



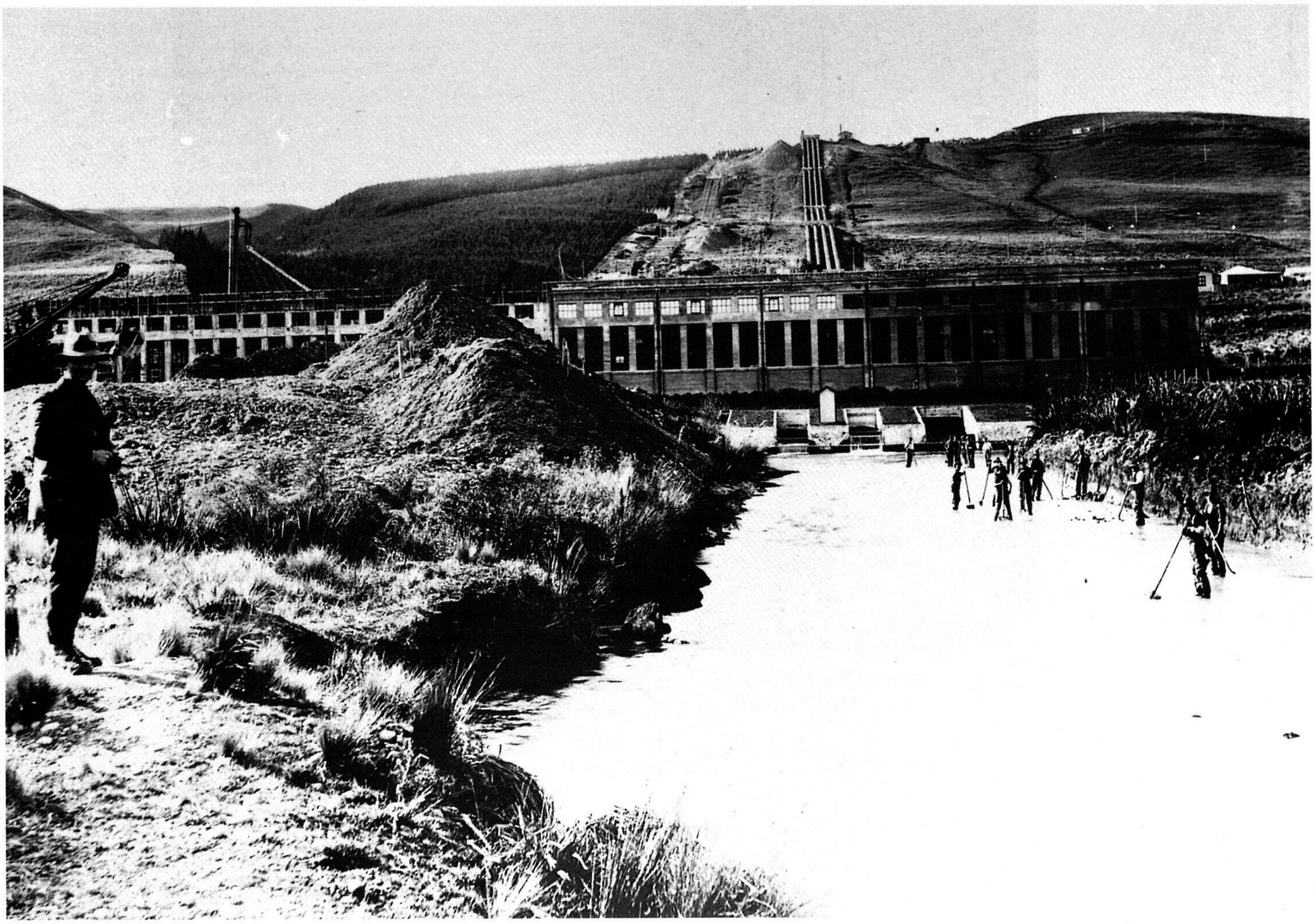
Transporting generator parts to the Lake Coleridge power station from the railhead at Coalgate in 1922, when additional units were added to the plant because of increasing load. This large trailer towed by a traction engine was used for moving heavy equipment. The trailer was later to give sterling service in the construction of both Mangahao and Tuai stations. It weighed between nine and ten tons, and could carry more than twenty tons. After Tuai was finished it was retired and, after various uses, was parked in front of the Urewera National Park headquarters.

In 1924 major extensions were made to the system, involving 100 men from Public Works and another 50 on the tunnel contract. A second intake at a greater depth in the lake to avoid shifting shingle, and a new tunnel and surge chamber were constructed. The second tunnel was to have been close to the first one, but was moved further away in an attempt to avoid seepages and rock-falls. The tunnel, started in February 1924, was completed in May 1926 after working three shifts 24 hours a day and experiencing major difficulties and three fatalities. The tunnellers encountered shifting, treacherous and waterlogged loose shingle. On 2 October 1925 the tunnel collapsed, killing three men at the face and trapping two others, who were kept alive by means of pipes driven through the debris to deliver air, food and water to them. They were rescued after nearly two days' frantic and extremely dangerous work. It took more than three weeks working in these conditions before all three bodies were retrieved.

The second surge chamber and new penstocks carried water to the extended powerhouse, where two 7,500 kW units were installed in 1926. Another unit of the same size was installed in 1930, increasing the capacity of the station from its original 4,500 kW to 34,500 kW.

The early 1920s also saw a thorough overhaul of the transmission lines to Christchurch, which had suffered from some harsh winters. Pin-insulator failure had been common, and was largely responsible for the shutdown in the 1918 snowstorm. Many insulators were replaced, and a third line was strung in 1922.

The Acheron River was diverted in 1930, when Lake Coleridge was far below its usual level because of severe drought conditions in the catchment. Increased demand for electricity made recovery of the lake level unlikely, so the diversion was completed rapidly and some 80 additional cusecs were flowing into the lake by December. That particular crisis had been surmounted, but it was too small a contribution to cope with the demand, and in the following year a plant was erected at Lyttelton to take emergency load until the Waitaki station was generating. This plant, based on four U-boat diesel engines, was



obtained from Britain as part of Germany's First World War reparations. Power was extended southwards to the Waitaki River in 1931 to assist with construction of the Waitaki scheme.

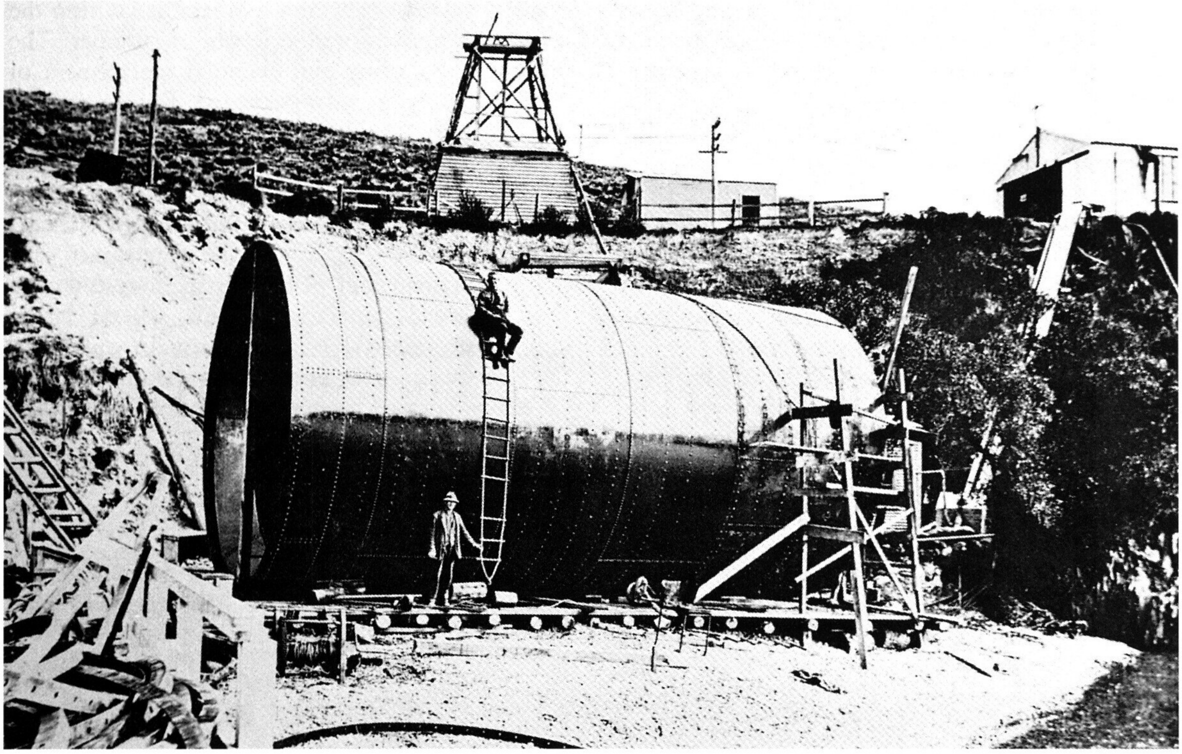
The Wilberforce River diversion was revived in 1950. The proposal was to divert water along a race leading to the existing channel carrying Harper River water to the lake, but matters were not taken further because of a lack of earthmoving machinery.

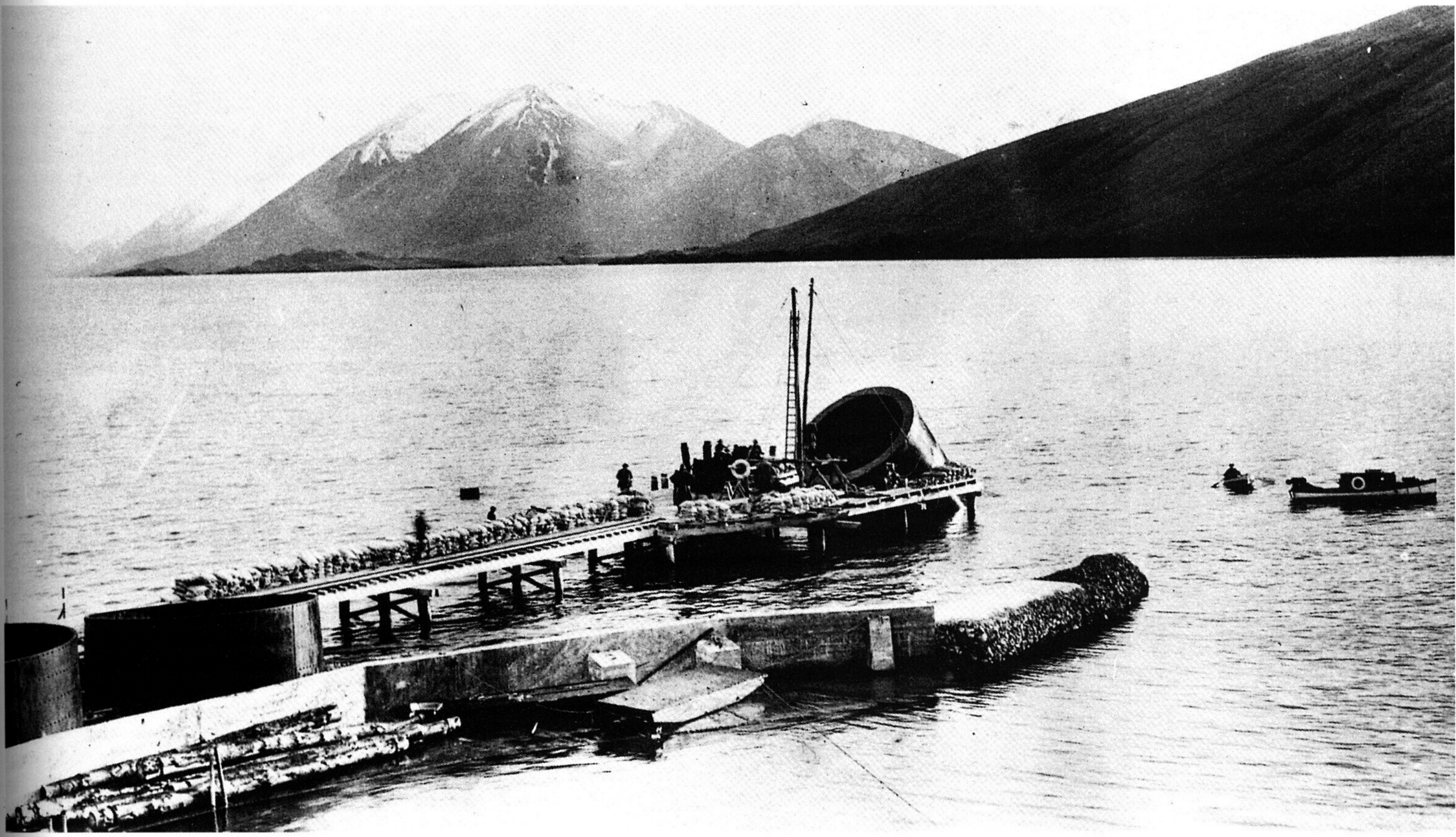
With machinery now readily available, the issue was reopened in 1974. The proposal was to divert part of the flow of the Wilberforce (up to 300 cusecs) by a gravel bank designed to be breached in floods. The water would be led by a canal to the Harper, where a second breachable gravel bank would divert water into a second canal to Lake Coleridge. The proposal depended upon a bulldozer and driver being stationed permanently on site to control the daily river flow and restore

Above: In 1924 the Lake Coleridge powerhouse was extended. These men are probably widening the tailrace to take the additional flow of water. The new section of the powerhouse can be seen at left behind the spoil, with the prepared additional penstock slopes running up the hill behind, alongside the newly planted pines that were to become a feature of the landscape.

Opposite above: An integral part of the extension to the plant in the 1920s was the construction of a second intake and a new tunnel. Here the steel intake cylinder is readied onshore for launching onto the lake.
AJHR, 1925, D-1

Opposite below: The intake cylinder being lowered to the bed of Lake Coleridge in 1925.





the diversion banks after floods. The additional water would allow the station to operate at a much higher load factor, and also enable consideration of replacement machines.

The scheme was approved in 1976 after an Environmental Impact Report had been prepared and water rights granted. The additional energy gained was cheap, particularly when compared with the cost of importing oil. The station was shut down from May to November 1977 while the diversion work was done, the tunnels were relined and generating plant refurbished.

A comprehensive survey of the station was undertaken in 1981. The old machines are noisy by modern standards, and their open-circuit cooling systems raise the temperature within the station to uncomfortable levels in summer. The need for upgrading and eventual replacement of these machines is now accepted. Future options are currently being studied, in the context of a Conservation Order which was put on the Rakaia River in 1988.

This first government hydro-electric scheme proved a success, and was the forerunner of a huge, sustained and planned state investment in hydro-electric generation. With several large-scale hydro-electric schemes now in operation, the scene was set for establishing the new concept of an integrated system of stations providing power across the country.

PART TWO

Expansion 1918–1945

CHAPTER THREE

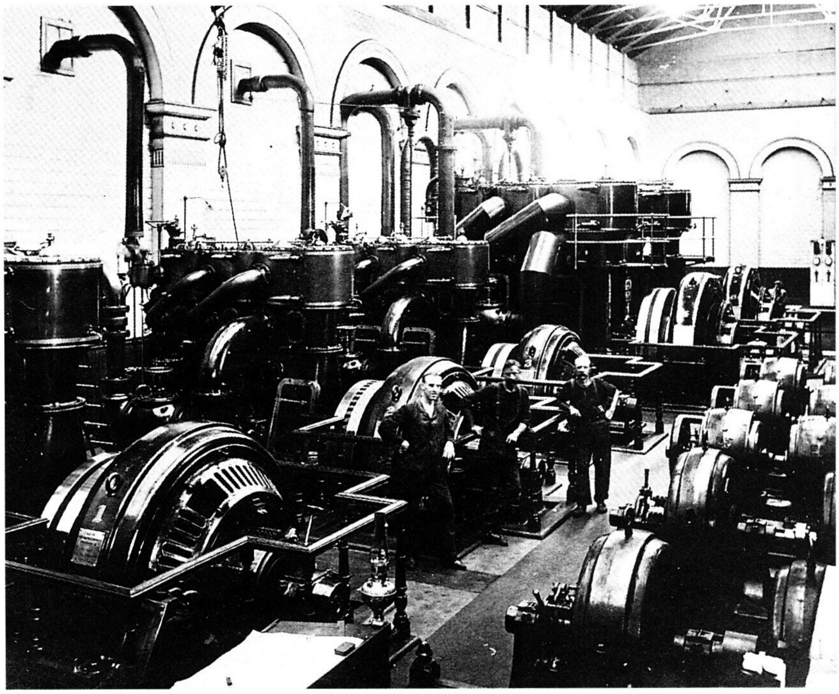
Towards a System

IN THE FIRST DECADE of the twentieth century, before the government became involved and at a time when it was not feasible to transmit electricity over long distances, generating capacity remained small and plants serving limited local areas proliferated.[1] Many local authorities built small hydro-electric or gas generating stations. These were often found in the North Island in prospering dairying communities. There were plants at Stratford, Parihaka, Patea, Hawera, Inglewood, New Plymouth, Te Aroha, Waitara and Eketahuna in the North Island, and Mataura, Gore, Ashburton, Timaru and Hokitika in the South Island. Some were run by local authorities, others by private companies. Taranaki was in the forefront of these developments. The many streams radiating out from Mount Egmont/Taranaki could readily be harnessed for small schemes, and the many dairy factories and dairy farmers were hungry for power.

In the second decade of the century many more local plants were installed throughout the country, most operated by the local authority concerned. Of the four main centres, Dunedin and Christchurch were well served by Waipori and Lake Coleridge respectively, while Wellington and Auckland had their own steam plants.

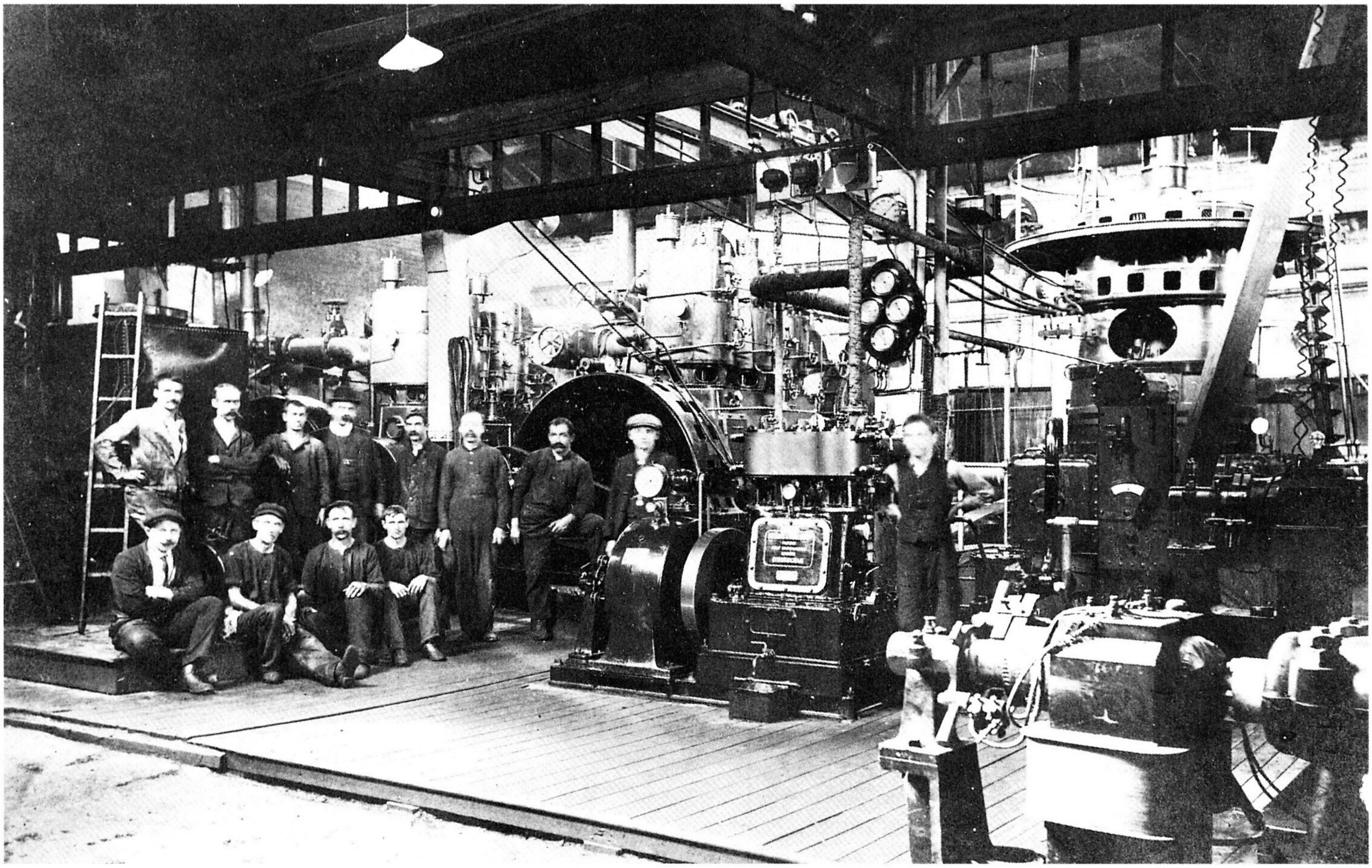
Wellington and Auckland

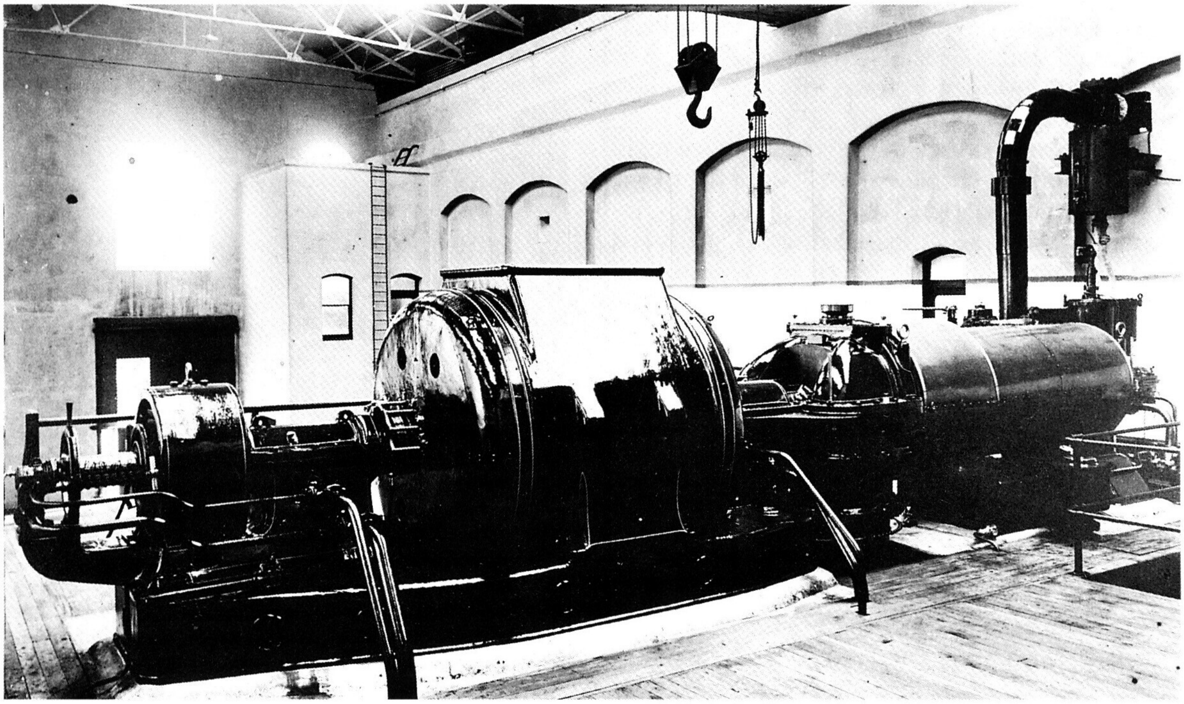
In 1902 the Wellington City Council decided to install electric trams. It commissioned the City of Wellington Electric Light and Power Company (the old Electrical Syndicate reconstituted) to construct and operate a station for the tramways on the corner of Jervois Quay and Wakefield Street. This was opened in 1904, and produced a total of 1,050 kW from four steam-driven DC generators. In 1905 the city purchased the street-lighting circuits from the company, and two generators with a capacity of 110 kW were installed at Jervois Quay to generate AC power for lighting. By 1910 the capacity of the Jervois Quay plant had reached 3,000 kW with the addition of a further three steam sets. The tramway plant was increasingly overloaded, especially at the peak half-hour after 5 p.m.; the boilers were pushed to their limits and any problems meant



The interior of the Jervois Quay station, Wellington, which supplied power for the city's trams. The photograph shows five of the steam-driven generating sets. This plant was built in 1904 and initially had four DC generators. Two AC generators were added in 1905, and a further three steam sets by 1910.

N. Rennie, *Power to the People*





that the trams slowed down. The addition in 1921 of a 1,000 kW turbine eased the situation. Jervois Quay was closed in 1924 when Mangahao power arrived in Wellington.

In 1907 the city council purchased compulsorily both the Jervois Quay and Harris Street operations from the company, and installed a vertical Curtis steam turbine and a 500 kW AC generator in Harris Street in place of the original horizontal steam engines. The council built a new plant on the Harris Street site in 1909 with a 1,500 kW Parsons turbo-alternator. By 1911 the number of consumers had reached nearly 6,000.[2] Another Parsons unit of the same capacity was added in 1914, and the Curtis turbine was brought back into service in 1919 to help with peak demand in winter.

By 1920 Wellington needed more generating capacity urgently. At first it was proposed that the Harris Street plant be extended, but much argument ensued. Eventually the council asked Lawrence Birks for a report, and he strongly advocated the construction of a new steam plant at Evans Bay.[3] After a substantial loan was raised in London in 1922, two Babcock and Wilcox marine-type boilers and a 5,000 kW Metropolitan Vickers turbo-alternator were purchased and installed at the Evans Bay station, which was commissioned in 1924. The two Parsons turbo-alternators were transferred to Evans Bay from Harris Street (which was closed down in 1925), and a 1,000 kW DC turbine was brought from Jervois Quay.

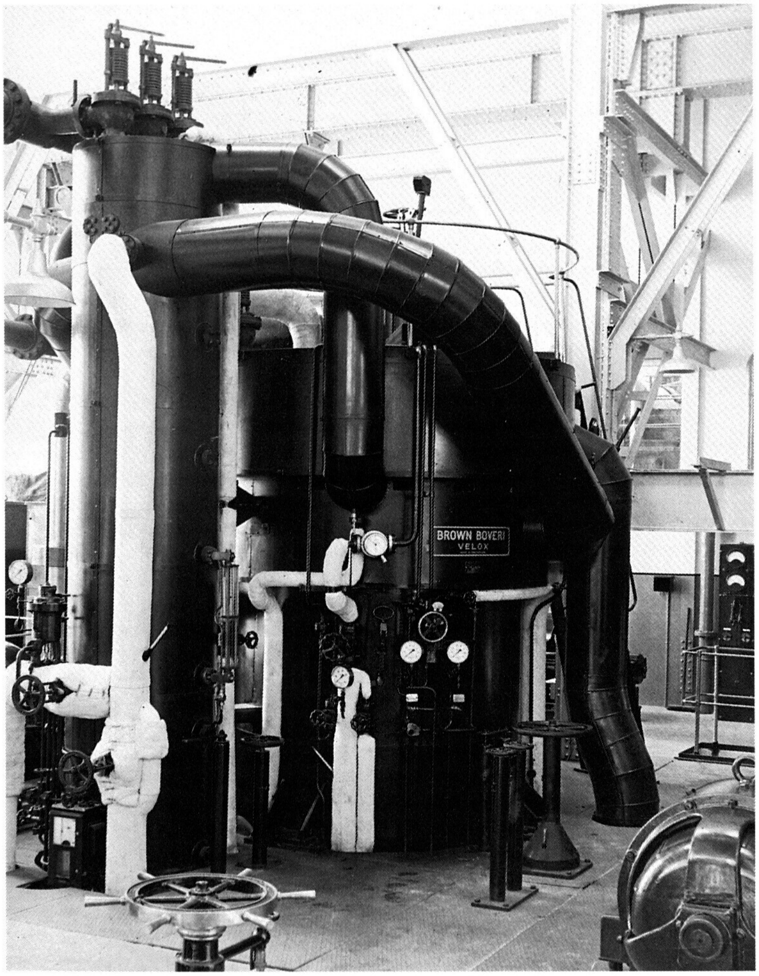
In the 1920s the city had to change from its highly successful 80-cycle single-phase 105-volt

Opposite above: The staff at the Harris Street station in Wellington, *c.* 1907, standing in front of a steam-engine-driven generator. To the right is the recently installed advanced vertical Curtis steam turbine driving a 500 kW generator.

Opposite below: The advanced 1500 kW Parsons turbo-alternator just after its installation in the new Harris Street plant in 1909.

Below: The coal-fired Evans Bay plant was commissioned in 1924. A 5,000 kW Metropolitan Vickers turbo-alternator was installed, and two Parsons units were transferred from Harris Street and another unit from Jervois Quay. After power from Mangahao became available in 1925, Evans Bay was used largely as a peak-load and standby plant, but during the wartime and post-war shortages it again became a base-load station.

system to take power from Mangahao.[4] This was the largest changeover undertaken in the country, involving some 20,000 consumers. How to go about it provoked considerable debate and disagreement amongst electrical engineers, which was ultimately resolved by referring the matter to Evan Parry, who was in the country on a visit in 1923. He recommended adoption of the standard system of 50-cycle three-phase 230 volts. Conversion of equipment and installation of a new distribution system, which involved much expenditure and work, took from 1925 until 1932. The entire distribution system was reconstructed, with more than 1,000 miles of line and more than 4,000 power poles erected. Many thousands of electrical appliances had to be rewired and reconditioned, and nearly 250,000 lights had to be replaced.



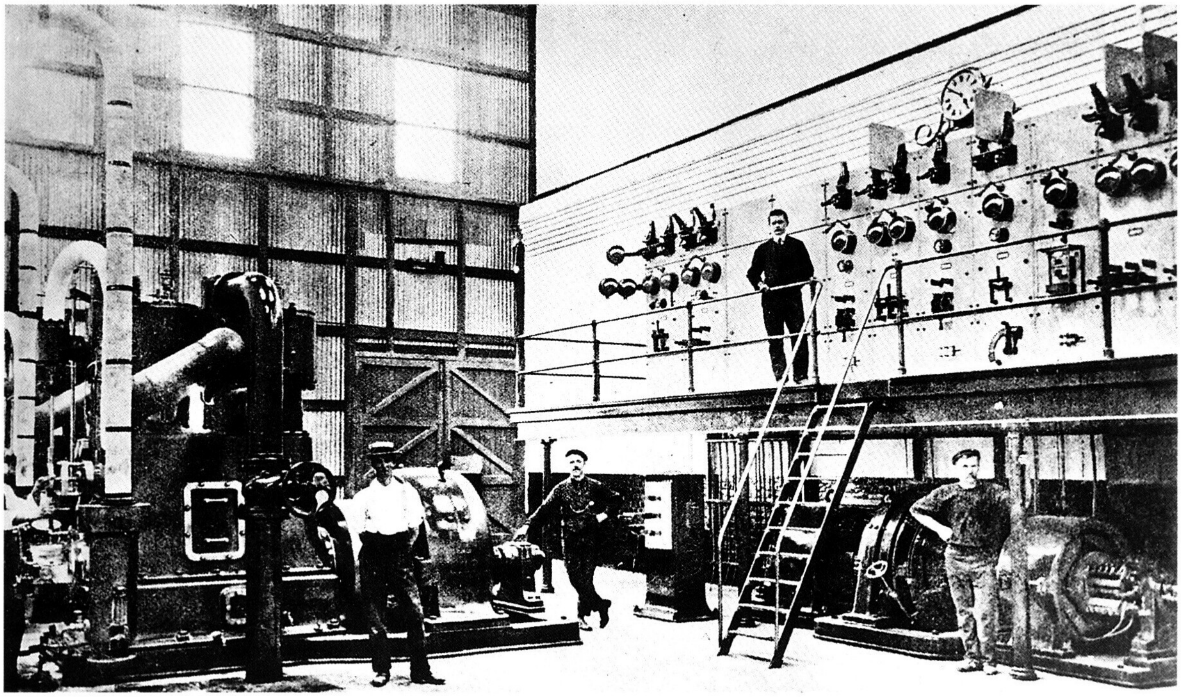
By the mid-1930s the Evans Bay plant lacked the necessary capacity and was too slow to respond in emergencies. It was decided to install two very advanced rapid-starting Brown Boveri Velox boilers and a 15,000 kW turbo-alternator. The boilers, one of which is pictured here, could reach full pressure in five minutes. They continued in use until the 1960s.

The city council and the government reached agreement in 1925 on a guaranteed minimum load from Mangahao and the use of Evans Bay as a peak-load and standby station. But within a decade Evans Bay lacked the necessary capacity and took too long to cope in emergencies. It was decided to extend the plant, and from 1936 two very advanced rapid-starting oil-fired Velox steaming boilers and a 15,000 kW turbo-alternator were purchased and installed. The boilers were capable of reaching full pressure in five minutes.

From this time until 1950, when the government purchased the station outright, Evans Bay was worked under contract to the government. The station was used as a base-load station for long periods during wartime and post-war shortages. The Velox boilers were overhauled in 1951. After Maraetai was commissioned at the end of 1952, favourable hydraulic conditions allowed Evans Bay to become a standby station, but in 1955 it was again required as a base-load station. By now the smoke and ash produced were making it very unpopular with local residents and, with the worst of the shortages over, the station was effectively closed at the end of 1959. From then until it was finally shut down in 1968 Evans Bay was used rarely and only at peak-load periods. The station's machinery was now old and expensive to maintain, and its noise and pollution levels had become unacceptable.

The direct involvement of the city council in Auckland in generation came at much the same time as in Wellington.[5] The Freemans Bay plant was commissioned in 1908. This comprised two Browett Lindley steam engines driving Westinghouse generators with a total capacity of 450 kW, and was located at the site of the city rubbish destructor. Within four months of the station opening, demand exceeded supply and coal had to be used as fuel to supplement the rubbish. A larger plant was needed quickly, and the council decided to build one at Kings Wharf.

After three years of construction work the Kings Wharf station was opened in 1913, upon which the Freemans Bay station was closed. Kings Wharf was to become the largest steam unit in the country until Meremere was commissioned. It originally supplied power to 1,500 consumers, with the surplus going to the tramways. Kings Wharf had four Belliss and Morcom steam engines



Auckland was slow to build a power station. This is a view of the interior of the first station, built at the rubbish destructor site in Freemans Bay, shortly after its commissioning in 1908. The station used heat generated by burning rubbish to develop steam. At left is a Browett Lindley steam engine driving a Westinghouse generator, and on the right, under the Westinghouse switchboard, is a generator used to charge a storage battery.
N. Rennie, *Power to the People*

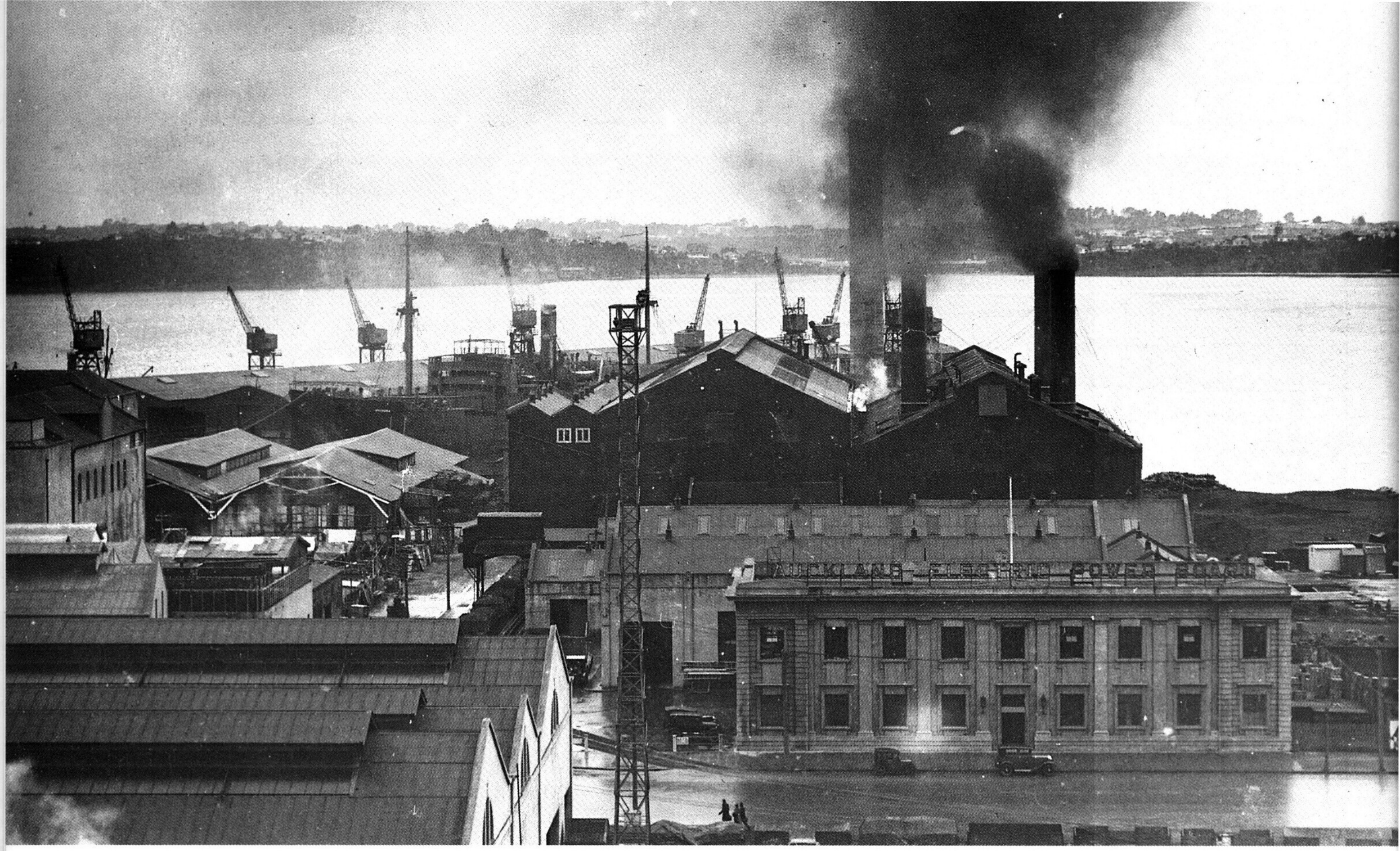
driving AC generators with a total capacity of 3,300 kW. Within two years a further four units were ordered, but war delayed completion of the extension until 1920. At that time the station had a capacity of 3,360 kW DC and 7,050 kW AC.

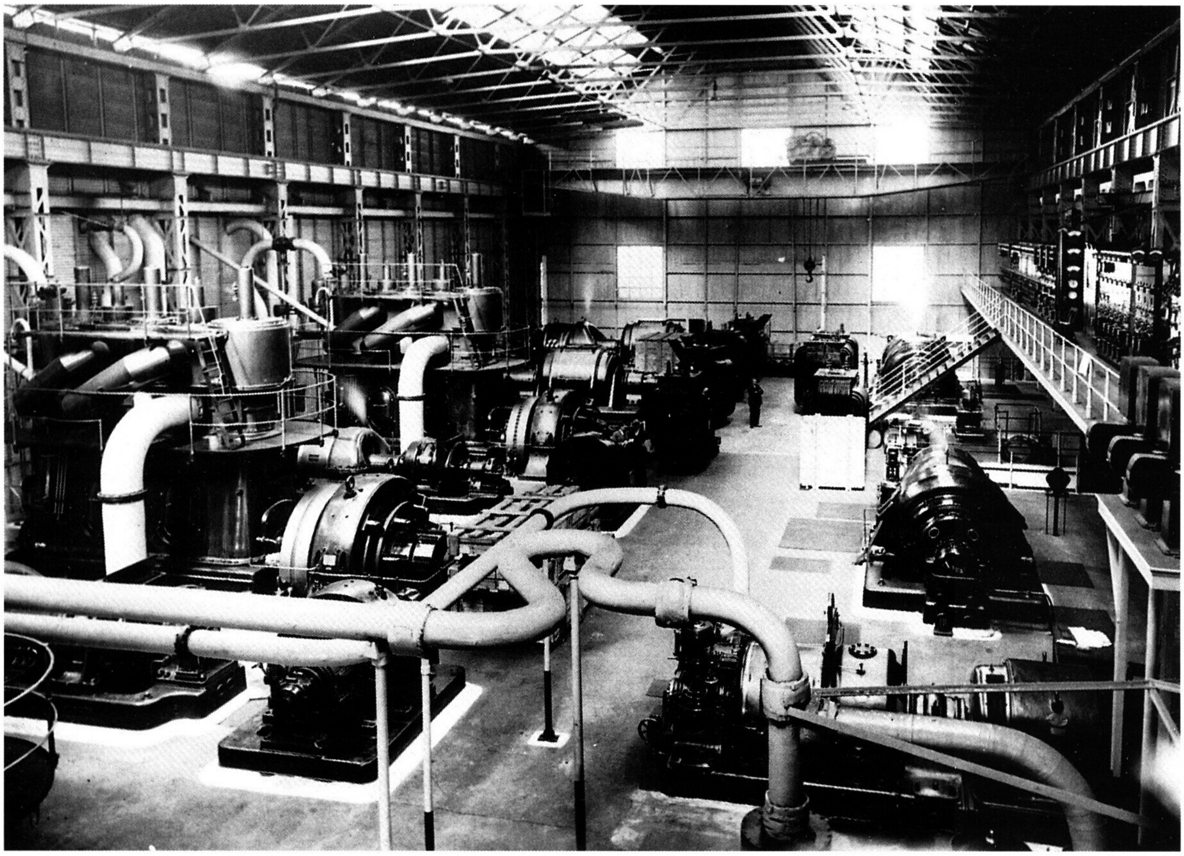
By 1920 the council had still converted only ten miles of streets from gas to electric lighting. It was only with the formation of the Auckland Electric Power Board in 1921 and agreement to take bulk power from Arapuni that the city was extensively reticulated. A comprehensive five-year street-lighting programme was begun in 1923. The activities of the power board encouraged demand and led to the addition of a further three units in 1922–23 and another in early 1925, but still demand outstripped capacity.

In April 1925 power from the Horahora station reached the Auckland area and provided some relief, but power from Arapuni was not available until 1929. Kings Wharf served a vital function in the intervening period, even supplying the Waikato with 5,000 kW when a fire interrupted service from Horahora. In this period its capacity was 18,000 kW AC and 4,500 kW DC.

In March 1930 the power board switched over to Arapuni power entirely, and Kings Wharf became a standby station. The ceremony at Kings Wharf marking the changeover to hydro-electricity was attended by several hundred guests, who listened 'while the rotors of three of the great machines slowly lost speed and the sound of spinning metal lessened and died out. At three o'clock exactly the powerhouse staff began to turn the handwheels; there was a rush of exhaust steam and the roar of generators changed to a softer note and died away. Arapuni power had officially arrived.'[6]

Only three months later Arapuni was decommissioned after the headrace cracked, and Kings Wharf became vital once more. Within a few days, 'throbbing once more with restless energy, the steam plant . . . [was] valiantly meeting the power and lighting demands of the city.'[7] Some 40 men were rehired, and by working three shifts kept the plant of 26 MW operating on overload. The government agreed to meet the cost of a new 15 MW steam turbo-alternator and boiler plant, which was installed rapidly and began operating by early 1931. The turbine ran unceasingly to supply the north. By 1932 Arapuni had resumed generation and Kings Wharf went back to standby status.


AUCKLAND ELECTRIC POWER BOARD



During the Second World War, Kings Wharf ran for most of each year, provided coal was available. The government bought the station in 1942 and disposed of the DC generators, which reduced the capacity to 27 MW. It was used often as a base-load station during the period of acute post-war shortages, but required constant maintenance and repairs. When Maraetai power became available at the end of 1952, Kings Wharf was shut down for a major refit. Maximum use was again made of the ageing plant from 1955 to 1960, but from that time until it was shut down in 1968 little electricity was produced.

Planning begins

Around the turn of the century the country's demographic balance had tipped in favour of the North Island, which by 1916 had 60 per cent of the population. Despite rapid urban growth, particularly in Wellington and Auckland, there were still no large-scale public generating plants in the North Island. The total number of electricity consumers in New Zealand had increased from 17,000 in 1912 to 45,000 in 1916.[8] By 1917 there were 2,500 consumers in Auckland, some 12,000 in Wellington, more than 4,000 in Christchurch and nearly 6,000 in Dunedin.

New Zealand was amongst the leaders in electric lighting at this time.[9] Almost one-third of dwellings were lit by electricity; only in the United States and Canada was the proportion higher. However, New Zealand's consumption of electrical energy per capita was relatively low because there was comparatively little industrial development.

After the success of the Coleridge scheme the government did not do much for a while because of the war. There was no money for new projects, and in any case few people were available to investigate, design or build large-scale hydro-electric plants. But the war did prepare the way for later developments by encouraging the notion that the state had an essential role in achieving 'national efficiency', and it did provide a breathing-space during which the development of hydro-electric resources could be planned. Furthermore, the wartime coal shortages in Europe created great interest in hydro-electricity and the technological development of machinery. Countries such as Norway, Sweden and Switzerland led the world in building large schemes and began manufacturing electrical equipment for export. At the same time, the problems of balancing fluctuating demands in different places led to the development of interconnected stations feeding a single 'grid' transmission system.

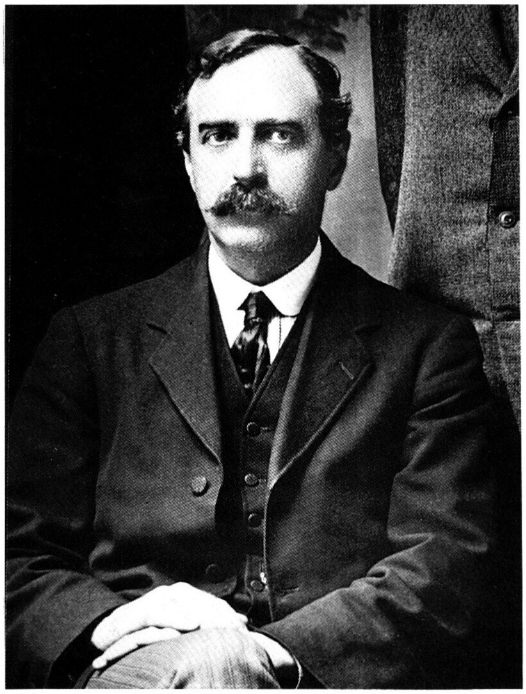
After a succession of dry seasons created water shortages, the estimated amount of power available from the various local authority schemes in the North Island had to be revised downwards, and larger-scale government schemes were now put on the agenda. Investigations of possible schemes in the North Island began in 1915, Kissel being transferred to head office for this purpose. By 1916 surveys had been made of the Aratiatia Rapids and Huka Falls on the Waikato, and of Mangahao in the northern Tararuas. The following year Arapuni, Horahora and Waikaremoana were surveyed, and the department began surveying transmission line routes north and south from Shannon, and from the Waikato River to Auckland.

Parry put forward three possibilities: a large station at Waikaremoana, one on the Waikato, or initial supply from three smaller but more conveniently located sources, which could be linked later to a large development and used as standby plant. Presumably Mangahao was seen as a prime candidate for a standby station, but it seems that the Hutt and Kaituna Rivers also came into consideration. Extensions to Horahora were also contemplated.

Parry soon became more certain of his plans.[11] His final report, in 1918, provided the basis for more than two decades of development. He envisaged an exalted role for electricity in society, arguing that it was 'one of the most essential agents in national reconstruction' and 'the nerve system of the community . . . touching every phase of national life'.[12] Furthermore, the 'national organisation of production and promotion of national efficiency was a function of a government'. Wise governments, he argued, were now at least co-ordinating if not directly control-

Opposite above: The coal-fired Kings Wharf station was opened in 1913, and from then until the 1930s, when Arapuni was commissioned, it played a vital role in providing electricity for the city. The station continued to contribute greatly during the wartime and post-war shortages, and remained in operation until the 1960s.
NZ Herald, 10 June 1930

Opposite below: The interior of Kings Wharf station in 1930. The old Belliss and Morcom steam engines driving alternators are on the left and the newer steam-driven turbo-alternators are on the right.
NZ Herald, 12 June 1930



Evan Parry was born in 1865 at Llanberis in Caernarvonshire, Wales.[10] He was educated initially in Bangor, and worked for a firm of marine engineers before moving to Glasgow University in 1890 to take a BSc degree and act as an assistant to Lord Kelvin. He worked with the City of London Electric Lighting Company as manager of the pathbreaking Deptford power station, which demonstrated the principles of economies of scale and long-distance high-voltage transmission, and for the British Thomson-Houston Company designing electrical machinery. He then became chief assistant to Dr H. F. Parshall, a consulting engineer involved in the electrification of tramways and railways and the formation of power companies. Parry took up his post as New Zealand's first Electrical Engineer in the Public Works Department in July 1911, and was to instigate far-reaching changes in the electricity industry here. He became Chief Electrical Engineer in 1913 and headed the Hydroelectric Branch of the department. His ideas on voltage, frequency and type of system shaped this country's development fundamentally. In 1919 he returned to England to join the English Electric Company as chief engineer, and in 1924 he became a partner in Preece, Cardew and Rider, for whom he was associated with many electrical-supply schemes in countries such as India, Ceylon and Australia. Parry was a member of the Institution of Electrical Engineers and of the Institution of Civil Engineers. He died on 17 December 1938 at Llandudno in Wales. He is commemorated by the Institution of Professional Engineers of New Zealand for his contribution to establishing a system of electricity supply in a quinquennial Evan Parry Award, for which the citation reads: '[This system was] well in advance of standards then in use in the world and showed Evan Parry's great foresight and courage as an electrical engineer. His decisions have been, and remain, a contribution to the economic and engineering welfare of New Zealand of the highest order.'

ling generation and distribution, rather than leaving the field to uncontrolled private enterprise. Parry's earlier experience in England had given him ample knowledge of the problems that could result from uncoordinated private development.

Parry's 1918 annual report set out plans for a series of large-scale state-provided hydro-electric developments, which with a total of 160,000 hp would provide more than three times the current capacity, and for a network of high-voltage 'point-to-point' transmission lines, running the length of the North Island, that would distribute this power. As he put it, the New Zealand system would comprise

> State enterprise planned on a national and comprehensive scale, with the Government as the bulk supplying authority, and with popularly elected District Boards as distributing authorities . . . . The scheme of national supply and distribution of power . . . was comprehensive enough to embrace within its scope a supply of power to every individual householder throughout the State, no matter how remote he might be, and was based on the principle that the more isolated the person was, the more he was in need of mechanical aid in order to render him an efficient producer and a worthy citizen of the State.[13]

Parry aimed to provide an additional one-fifth of 1 hp (150 watts) of electricity per head for the existing population of 650,000. The plan, which took into account the relative concentration of regional populations, would make power available 'in the interest of national economy and production . . . for every householder in the

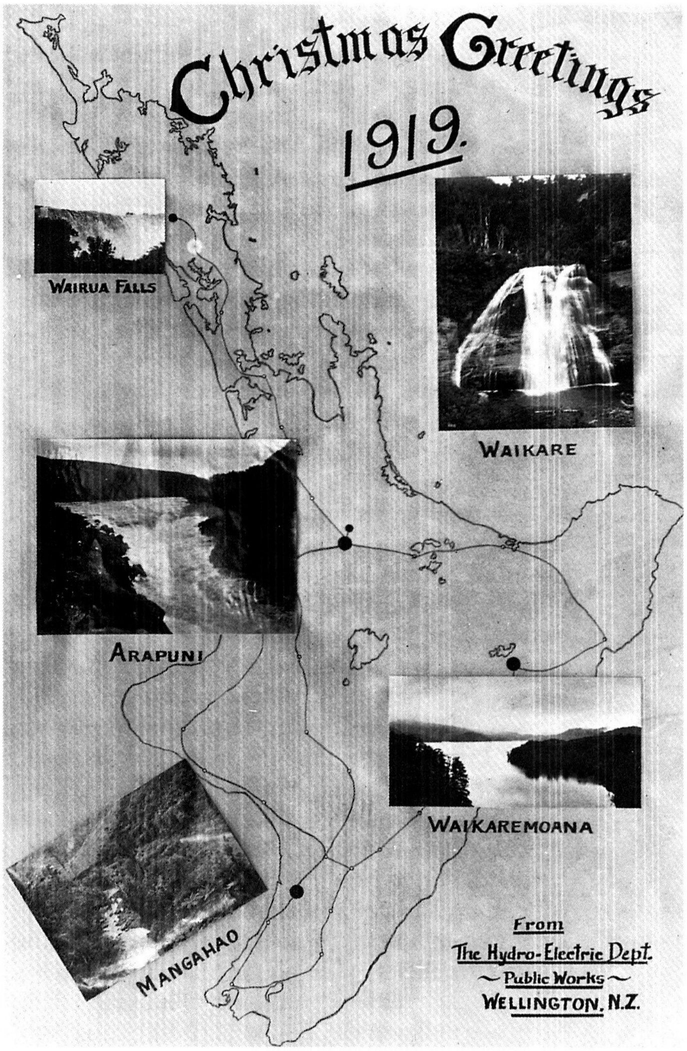
North Island, and for any industry requiring the supply of power . . . for main-line electrification, light railways, coal and other mines, for winding, pumping, ventilating, and smelting, and for any other purpose'.[14]

Parry's thinking reflected the international impact of the war, which had led to greater emphasis being placed on much larger stations and on the interconnection of systems used for various purposes, such as lighting, electric motors and electrically based industries. Economies of scale and co-ordination and systematisation became key concepts at this time.

His proposals would cost £7.3 million. Some £2.1 million would be devoted to the construction of three new schemes, while a massive £4.7 million would go towards creating the transmission network, including substations. As G. P. Anderson, who was then responsible for field surveys of transmission lines, commented: 'one of the principal, if not the biggest, undertakings will be the erection of transmission-lines to distribute the power to the various centres, and also to country districts.'[15] This aspect of the plan should not be underestimated, since Parry's vision relied upon extensive reticulation and the widespread provision of electricity geographically, rather than, as in many other countries, the supply of relatively few large industrial consumers.

Parry stated as fundamental principles that generating plant should be centralised as a few large units, with 20,000 hp as a minimum economic size, and that the capital cost should not exceed £20 per horsepower of capacity.[16] Centralisation would permit savings in capital, fuel and labour, and provide greater flexibility in use. One critical factor was the ability of a large plant to supply a connected load from a variety of sources, with peak individual demands in aggregate much larger than its capacity but distributed through the day. Small local plants were not capable of fulfilling this role. Parry asserted that, in strictly engineering terms, the advances made in the transmission of electricity might permit a single station for the entire North Island. But he concluded that this was not a practical proposition because of the difficulty of constructing and maintaining the resulting long transmission lines over rough terrain. Furthermore, there was no single source capable of supplying all the electricity needs of the North Island in the long term.

He suggested instead that three stations could each provide a regional supply. Mangahao (rather than the frequently touted Hutt River, which would require a very high dam) was earmarked for Wellington. With an estimated total of 24,000 hp, Mangahao would be relatively costly per unit and not much above Parry's minimum size, but had the best location in relation to demand. As for Auckland, Arapuni (with 96,000 hp) should go ahead if the site foundations proved suitable; if not, Aratiatia was the best option. In the mean-



By 1919 the Hydro-electric Branch felt confident enough to issue a Christmas card with its proposed schemes of Mangahao, Arapuni and Waikaremoana and the private scheme of Wairua Falls in Northland emblazoned on it. The 'Waikare' photograph is something of a mystery, but may be of the Waikaretaheke River, which emerges from the ancient slip at the outlet to Waikaremoana. Equally interesting is the sketched-in network of transmission lines encompassing virtually the entire North Island. This was to be built over the following decade.

time, to help maintain supply and create greater demand until the large Waikato development was commissioned (which would take some time), the government should purchase Horahora. Waikaremoana, with 40,000 hp, would eventually provide for Hawke's Bay and supplement the needs of Wellington, but was to be deferred until the Napier–Gisborne railway had been constructed. The railway line would open up a route for a transmission line, and could itself be electrified.

The department would transmit power to its own substations along some 1,100 miles of 110 kV line using suspension insulators (the routes suggested closely match modern lines). Use of this voltage — which could be transmitted economically for 100 to 150 miles — was in advance of much of the world. (The first line of this voltage had operated from 1906 in Michigan, USA.) The 29 main substations located strategically along the network of high-voltage lines would deliver power at 11 kV, or in some cases 22 kV. There would be another 300 miles of 'branch mains' at lower voltages to substations off the main lines. Reticulation from these would be the responsibility of local bodies, though where there were several large loads close together, the department might supply direct. Retail distribution was to be in the hands of local authorities or other bodies awarded licences to supply.

Parry did not really explore possibilities for the South Island because at that time the island was reasonably well provided for. He set out only briefly the tentative shape of a system that would carry Lake Coleridge power north to link with stations in Marlborough and Westland and south to a station between Coleridge and Waipori, and would link Waipori with a plant at Monowai. Extensions to Coleridge and Waipori would be required. However, this was no more than an addendum and could not be taken further at that time because of staff shortages in the Hydro-electric Branch.

Later, a parallel but less ambitious plan for the South Island was developed and articulated officially in the 1921 annual report.[17] Funds for this were tentatively committed in 1923, and the proposals were discussed further in 1924. At this time branch staff were being released from work on the Mangahao scheme, and the Waitaki was being eyed with interest. More immediately, apart from the construction of Monowai, which was in the hands of the Southland Electric Power Board, the emphasis was on extending existing plants and linking them together with a 66 kV main transmission line that would use pin insulators. This decision was made on the basis that less power would be required, that Coleridge was already transmitting at that voltage and Monowai would do the same, and that the South Island's population was more concentrated than the North's into main centres with generating plants close by. It was proposed that some 760 miles of line, roughly half of it double line, be constructed between Waipara in North Canterbury and Invercargill, including Alexandra and Roxburgh in Central Otago. Feeder lines to power boards were to be of 33 kV or 11 kV. The regions that would miss out — Marlborough, Nelson and the West Coast — could manage, it was argued, with local plants supplying a demand concentrated on population centres.

The proposal to create a linked network also raised the issue of a standardised system of electricity generation. The many existing local plants generated electricity in a bewildering variety of forms.[18] In 1920, when the government adopted three-phase 230-volt AC at 50 cycles per second as the standard, 29 of a total of 55 plants still generated DC current at various voltages. Of the AC plants, eighteen generated three-phase 50 cycles per second electricity, and almost all the others single-phase AC at a range of different cycles. Those plants that generated electricity on the standard system, however, provided nearly 60 per cent of total capacity. The implication of Parry's plan was that there would be a rapid move towards a fully integrated homogeneous system, with standardised current and voltage supplying a great variety of needs.

The origins of power boards

In the same year as Parry produced his plan the Electric-power Boards Act 1918 was passed. This legislation was to set the pattern for the reticulation of electricity from that time onwards. The concept behind it was to reverse the existing concentration of electricity supply on cities and towns. The Act encouraged the extension of power supply to rural districts, which would effectively be subsidised by urban areas.

With William Massey in power from 1912, the political interests of farmers, and particularly smaller dairy farmers, were strongly represented in government. Nineteenth-century changes in political structure following the abolition of the provinces had created a multitude of weak counties with insufficient rating bases to bear the high costs involved in reticulating electricity. It was clear what would happen if this function was left to the existing local authorities. Great differences in the cost of reticulation per consumer, along with unequal abilities to raise and service loans, would see to it that the larger urban authorities would manage well and rural ones poorly. Larger, separate and distinct local bodies would be required if electricity was to get into the countryside.

The erection of electric lines had been governed by the Electric Lines Act 1884, under which local authorities and others had to gain permission from the government. From 1908 the same authority had to be obtained under the Post and Telegraph Act. In 1915, with the passing of the Lake Coleridge Water-power Act, reticulation of electricity was actively encouraged for the first time. This Act enabled the local authorities drawing power from Coleridge to supply electricity and raise loans for the purpose. This established in principle a division between the retail distribution of electricity by local authorities and generation and bulk transmission by central government.

In the words of the annual report of 1920: 'The function of the Government in connection with hydro-electric supply consists essentially in the construction of main generation stations and the main transmission-lines and substations from which the power will be sold in bulk to the local distributing authorities. The latter will be left the duty of reticulation and retail sale.'[19] In 1917 the State Supply of Electrical Energy Act formalised the government's financial role. The Aid to Water-power Works Account established in 1910 was renamed the Electric Supply Account. Into it went both loans raised for hydro-electric schemes and income received from the sale of electricity. This Act provided the commercial basis for government bulk supply of electricity (see the Conclusion for a discussion of the bulk supply tariff).[20]

At this time electricity distribution was confined mainly to larger boroughs and cities. In 1919 there were 64 distributing authorities other than the government, mostly boroughs but including eleven private companies.[21] (With the government's purchase of Horahora these companies produced only a tenth of all power.) The government generated one-third and local authorities more than half of the total supply. Of the overall capacity of 43.9 MW from 54 plants, water power provided 24.3 MW. Steam was the other major source, with 15 MW, while gas and oil accounted for the balance. Major contributions were made by Lake Coleridge, Waipori and Horahora, and the steam plants at Auckland and Wellington. The four main centres consumed 60 per cent of the total power generated and provided 32,665 of the total of 54,926 consumers. Almost all the remainder went to smaller towns; it was estimated that fewer than 1 per cent of consumers were in rural districts.

The government had sold its first power from Lake Coleridge to existing local authorities. In its headlong rush to demonstrate Coleridge's viability, contracts were made with a dozen boroughs and county councils, some of which had only a few hundred potential consumers. That this was a weakness was soon recognised.

The essence of the Electric-power Boards Act was to provide for the local reticulation and retail distribution of power bought from the state. The Act encouraged the combination of districts to form suitably sized power boards, which were given the power to raise loans. A board could be set up following a petition from one-quarter of the ratepayers in a proposed district. Nothing in the Act, however, compelled existing generating authorities to join with their rural neighbours. The government had the power to veto proposed boundaries, declare the inclusion of additional desirable areas, and order the combination of districts. The Act also allowed power boards to generate electricity themselves, but only subject to government permission and power of purchase. The government would retain control over the nature of any such generating works and transmission lines, so that consistency with its own planned system could be maintained. Generation was to stay firmly under government control.

In formulating the original bill, A. W. Rodgers, chairman of the Southland Progress League, had been motivated by a vision of joint town and country enterprise that would give equal access to all. The impetus for the creation of power boards came from Southland, where no major supply existed. The Southland Progress League first saw electricity as a means of bringing industry and prosperity to the province some 50 years before Manapouri power brought Comalco to Tiwai Point. The league was also aware that government development after Coleridge was to be in the North Island, and realised that only by local effort would immediate progress be made.

Rodgers had conceived of 'a grand electrification scheme' while farming near Ohai. In 1916 he became the first chairman of the Ohai Railway Board, a private company with a permit to build and operate a railway within a defined district under the terms of the Local Railways Act 1914. The Electric-power Boards Act applied similar principles to electricity. Together with Invercargill's Electrical Engineer, he drew up proposals for areas to be supplied, and made plans for the establishment of a board with rating powers over the whole area. As part of this process Rodgers also drafted the parliamentary bill.

The MP for Awarua was Sir Joseph Ward, then Minister of Finance, Postmaster-General and Minister of Telegraphs. Rodgers wrote to him about the urgency of making cheap power widely available in Southland to stop the 'ebb-tide' of population drifting north; the province could not wait for government-supplied power. Ward, in introducing the bill in April 1918 on behalf of the Southland Progress League, described it as dealing comprehensively with most important matters affecting the dominion.

The bill applied to the entire country. It was argued that electricity was the key to industrial and agricultural development and to domestic comfort. It was a national asset that should be equally available at the same cost to all. Birks supported this view, and wrote to Parry in 1918 criticising proposals to establish different suburban and country rates. As he said in a report to the Southland Progress League,

> the country supply is more important because it is not a question of cheapening and popularising an existing public service, but of giving a service not otherwise available. More than this, it offers one of the fundamental necessities of civilised life — the public distribution of energy for light, heat and power to the farming community to whom it is of the utmost importance and value in increasing their output, reducing the labour of farming, and attracting a better class of labour, particularly the young people of the farmer's family, to stay on the farm instead of rushing to the cities, and thus rendering a service of national importance.[22]

With Birks' report received and positive encouragement from Parry, the league impatiently awaited the enactment of the Electric-power Boards Act. In December 1918 Ward sponsored its final reading, pointing out that the government retained ultimate control of water-power resources, since the Public Works Department must sanction all proposals. The heavy post-war commitments of the Public Works Department made local development desirable if national availability was to be achieved within a reasonable period. Both sides of the House were in general agreement with the bill, which was duly enacted on 2 December 1918.

Birks believed that power board districts should have an absolute minimum population of about 5,000 in cases where geography ruled out larger units.[23] Otherwise, the desirable minimum was nearer 20,000. A district should combine towns with the rural hinterland they served, so that there was a 'natural community of trading interests'. It was hoped that each board would take the whole output of one of the department's major substations. Birks drew up a list of 54 potential board districts. The Thames Electric Power Board, while not the first formed, was the first to supply electricity, when in March 1921 it provided Paeroa with power from Horahora.

At first there was little government interference with proposals for power board districts, but soon it was realised that action would have to be taken to ensure the principles of the Act were realised. From 1920, petitions had to be submitted to the Minister for approval, and he could make any alterations in boundaries thought necessary. F. T. M. Kissel, Chief Electrical Engineer from 1924, brought much pressure to bear, often in public. Most commonly he had to force the dropping of proposals that would have meant towns shirking what was seen as their responsibility to rural areas. The desired collaboration between town and country was not always achieved. Of the four main centres, only Auckland joined with the adjacent areas as part of an inclusive power board. The pattern was set by local needs and local interests rather than by the national plan devised in the Public Works Department.

It was intended that the power board system would eventually cover the whole country. The Public Works annual report of 1922 made this explicit, and added that it was a serious question 'as to whether the procedure should not be mandatory instead of permissive — that is to say whether the whole country should not be incorporated in electric power districts'. Later in the year J. G. Coates, Minister of Public Works and a driving force in the extension of reticulation, said that he had used his 'strongest influence', and would continue to do so, to induce towns that had been on their own to join with neighbouring power boards. Many territorial authorities did join a board and sell their existing electrical enterprises to it, but it was clear that some would not do so voluntarily.

By 1924 Birks felt able to state that the potential for 'electric-power supply to isolated farming districts and country consumers is probably being exploited, in proportion to its population, more extensively in New Zealand than in any other country in the world'.[24] Despite the problems, it was this Act and the fact that the government held a virtual monopoly over the generation and bulk transmission of electricity that gave the rural districts of New Zealand earlier and greater access to electricity than those in almost any other country. In the United States little progress was made because of the lack of profit in such endeavours, while in Britain reticulation was largely confined to urban centres.

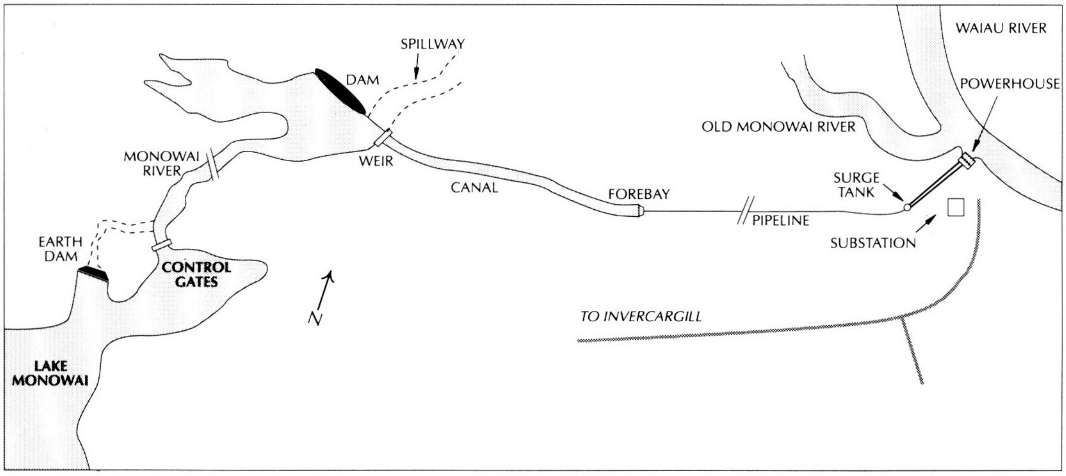
Unfortunately, from the point of view of Birks and others, the Municipal Corporations Act 1920 cut across the 1918 Act. It gave municipalities the right to build stations and distribute electricity, and to transfer funds from their profitable electricity departments to other activities, which had been prohibited by the Electric-power Boards Act. This encouraged local politicians to preserve their income-generating enterprises and hindered any coming together of rural and urban interests. Perhaps the vision of a unity of town and country in supplying electricity was too idealistic and ignored the realities of local politics, but the 1918 Act was certainly instrumental in giving many rural districts early access to electricity.

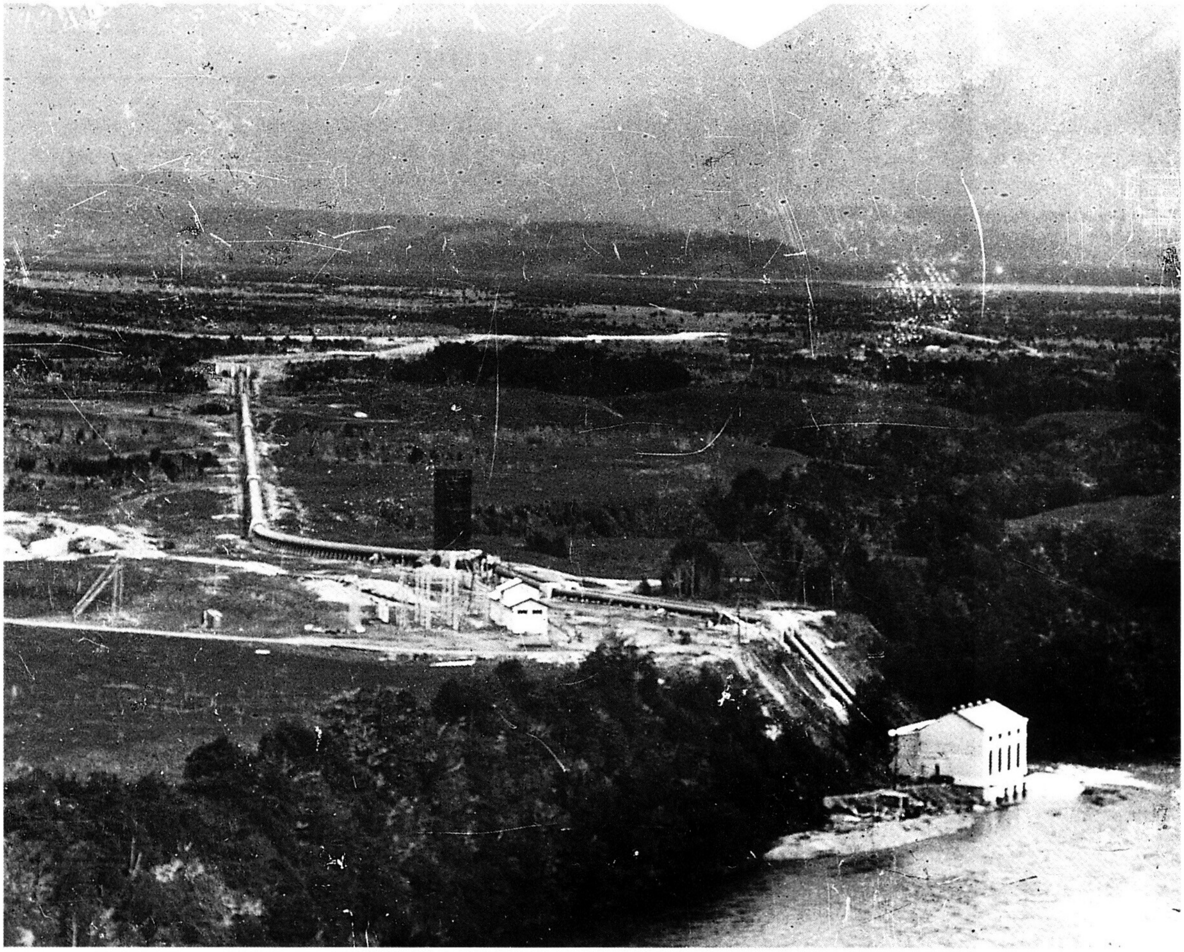
Southland did not hesitate. It set up the country's first power board and quickly initiated a major hydro-electric project.

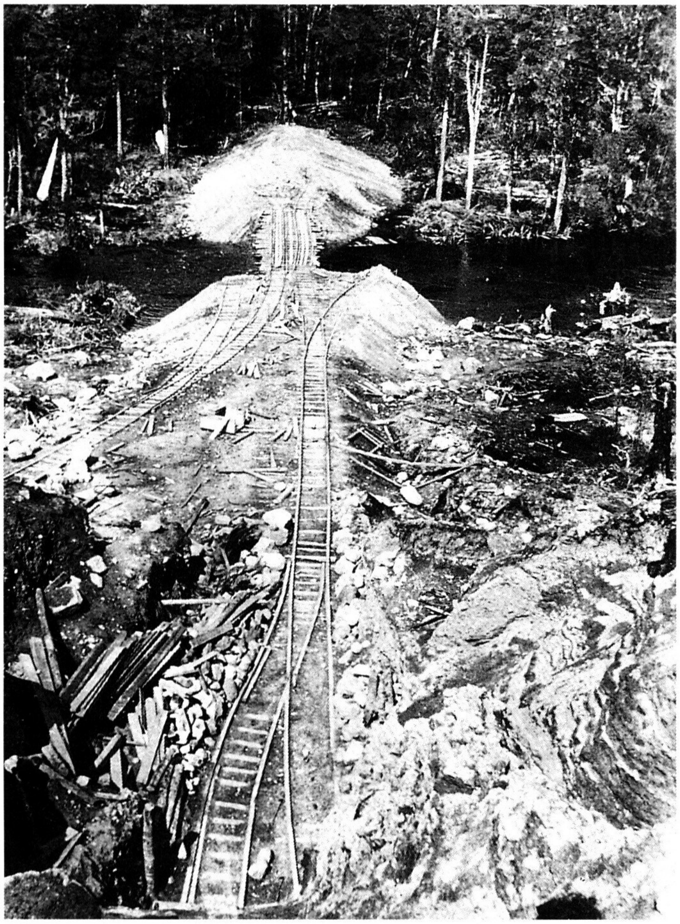
Monowai

Lake Monowai lies at an altitude of nearly 700 feet some 65 miles from Invercargill, encircled by mountains except at its outlet, the Monowai River.[25] The river, with an average flow of 500 cusecs, falls 250 feet within four miles to the Waiau River. The earliest surveys of New Zealand's hydro-electric resources had made clear the very large potential for development in the lake and river systems of the far south and south-west. Prior to installing a steam plant for its tramway system, the Invercargill Borough Council, mindful of the success of Dunedin's Waipori scheme, had engaged a consulting engineer to report on Lake Monowai as a source of power. However, the level of demand in 1910 made steam a more realistic proposition than Monowai, which would have required lengthy transmission lines.

Monowai: Constructed 1922–25. Head 154 feet. An earth dam at the outlet of the lake raised its level by 8 feet, and a new outlet was created nearby with a concrete dam and four sluice gates. A weir and spillway 4 miles downriver created a headpond. A canal of 2,900 feet led to a pipeline of 3,400 feet and a surge chamber. Two penstocks took the water to the powerhouse on the west bank of the Waiau River. Two horizontal double-runner Francis turbines drove two 2,000 kW three-phase 6,600-volt generators. A third penstock, turbine and generator were added later to increase capacity to 6,000 kW. Power was transmitted at 66 kV using pin insulators over 160 miles of line to Invercargill and Gore.







Above: The Monowai power scheme involved an earth dam at the outlet to Lake Monowai and a canal and single pipeline running across country to the powerhouse beside the Waiau River. The tall surge chamber at the end of the pipeline can be seen in the centre behind the substation. This scheme was built by the Southland Electric Power Board as part of an ambitious plan to reticulate and supply power throughout the province.
Alexander Turnbull Library

Left: This photograph shows the construction of the low earth dam for the Monowai scheme, which raised the level of Lake Monowai by eight feet.

Opposite: The large pipeline for the Monowai scheme under construction.

In 1916 Kissel, then Office Engineer in the Public Works Department, reported on Southland to Parry, and supported the view that it would be too expensive to develop Monowai unless some special metallurgical or chemical manufacturing could be developed in the region. But the Southland Progress League was not so easily discouraged, and decided to promote the Monowai scheme itself while looking to the government for advice and permission. Parry sent Lawrence Birks to make a preliminary assessment in 1917.

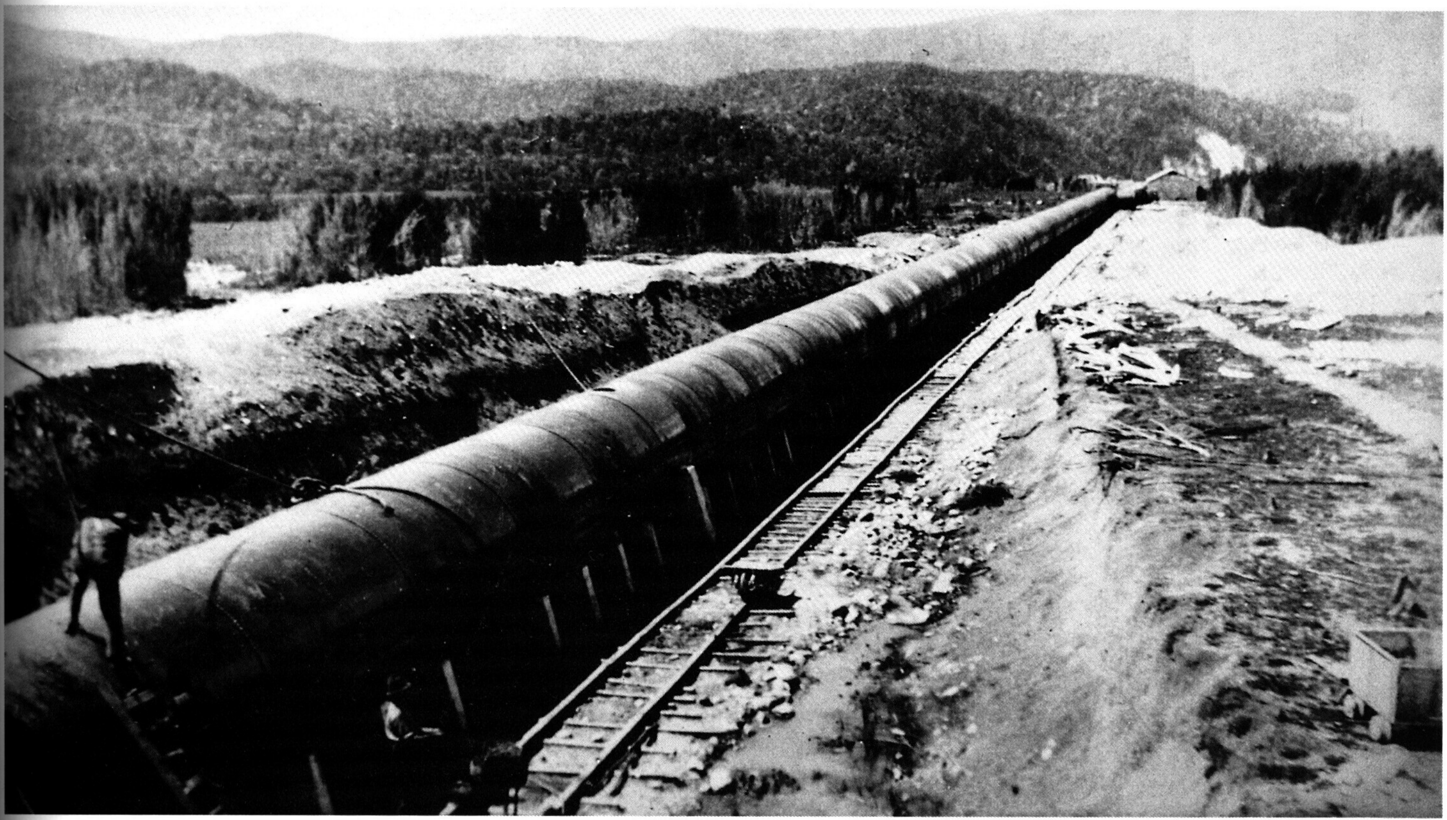
Birks examined both the Monowai area and the less-accessible Lakes Hauroko and Poteriteri. He recognised that co-operation amongst local authorities would be essential if such a large scheme was to succeed. At a conference of local bodies in Invercargill in January 1919, Rodgers successfully proposed the formation of the Southland Electric Power Board, and that the electricity generated should be sold in bulk to borough councils and town boards, which would undertake local reticulation and retail sales.

In November 1919 the Southland Power Board was the first in the country to be gazetted. It covered the whole of Southland, although Invercargill was to remain a separate supply authority. The board acted quickly; a poll in March 1920 approved the raising of a large loan to build the power station at Monowai.

It was planned to increase the natural storage of Lake Monowai by damming the Monowai River, and to create a new outlet nearby with sluice gates to control the release of water into the river. Water was led from a headpond created four miles downriver to the powerhouse on the Waiau River by a canal, pipeline and penstocks. The transmission lines were routed for the convenience of Gore and Invercargill. From the main switching station at Winton, one line led to a substation at Gore and the other to Invercargill.

The work was authorised in April 1920, but construction did not actually begin until January 1922 because of post-war difficulties. The station was opened on 1 May 1925 with two machines operating. Two years later the third machine was commissioned.

The board began to reticulate the province enthusiastically even before power was available from Monowai. By the time the station was operating, more than 3,300 miles of line had been erected — far more than was served by any other scheme in the country. Some 1,600 miles was at 11 kV. Monowai supplied nearly 6,500 consumers initially, and the number more than



doubled in the next five years. One of the power board's early salesmen remembers how he drove his car over 'paper roads' to isolated farms to spread the sale of power. He promoted electric ranges, ordered from the board's illustrated catalogues, which were too large to fit inside some houses! The Southland Power Board actively promoted the sale of electric power, and its example was quickly followed by others who wished to take advantage of the new legislation to raise funds for both generation and reticulation in areas not served by the government.

Sadly, the reticulation of such a large area, when added to the burden of financing Monowai, proved to be beyond the resources of the Southland board. Its operations were never profitable, since both Bluff and Invercargill retained the profits of their sales, taking only bulk supply from the board. From 1925 onwards the board was forced to strike a rate annually to cover its losses. In 1936 the board approached the recently elected Labour government for assistance in renegotiating a loan in London. However, this went against Labour's nationalising philosophy and was refused. Local ratepayers in a referendum voted overwhelmingly to support a government takeover. Monowai and other Southland Power Board assets were purchased by the government, which has since had a unique role as the retailer of electricity in Southland.

CHAPTER FOUR

Parry's North Island Schemes

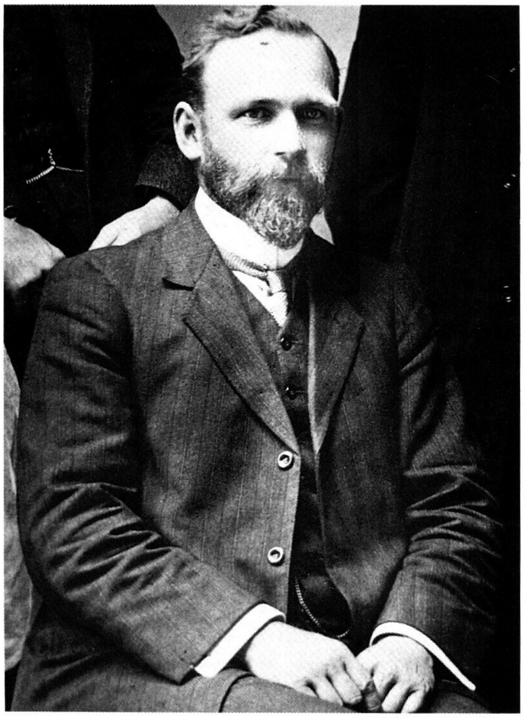
PARRY HAD LEFT NEW ZEALAND by the time Birks, as Acting Chief Electrical Engineer, produced the annual report for 1919. Birks became Chief Electrical Engineer in the same year. In the meantime, surveys of possible North Island schemes had been completed. Birks' analysis of existing capacity supported Parry's case for an interconnected network of large stations. He argued that additional capacity was required urgently.

The Electric-power Works Loan Act of 1919 set down a development programme that was much expanded in comparison with the £500,000 per year authorised in the 1910 Aid to Water-power Works Act. Some £6.8 million was allocated for a wide range of expenditure: construction of the Arapuni and Mangahao projects, extensions to the Lake Coleridge scheme, the purchase of and extensions to Horahora, and surveys of Waikaremoana and the Waitaki River. Work on access to Mangahao had already begun, and exploratory shafts were sunk at Arapuni. Parry, seeing the Horahora plant as wasteful (it used only 4,000 hp of a potential 9,000 hp), had proposed that the government take it over and distribute its power more widely. This was now done, which substantially increased the government-provided capacity.

The 1920 Finance Act made a further provision of £3.5 million, largely for Waikaremoana but also for extensions to Lake Coleridge and investigations of the Kaituna River and other possible schemes.

J. G. Coates was appointed as Minister of Public Works in 1920, and held this portfolio until 1926 and again from 1931 to 1933.[2] He played an important role in shaping public works and was to bring about a number of significant changes. Recognising the importance of hydro-electric development, he provided the political support needed to implement Parry's plans. Coates' responses to the post-war labour shortage were to engage in a mechanisation programme and to improve working conditions. A considerable sum was allocated for the purchase of machinery. Tunnellers began to use air-compressors and special rock drills, and steam-shovels ('steam navvies'), steam locomotives, lorries, caterpillar tractors, concrete mixers, power-driven winches and drag-line excavators gradually became more common.

At that time working conditions and pay on public works were particularly bad. Public works labourers — first railway construction and before long hydro-electric construction workers — began joining the New Zealand Workers' Union. The first agreement regulating rates of pay, the cost of food and working conditions was made in 1920 between the department and the Workers' Union. This also provided procedures for consultation and the settlement of disputes, and stipulated standards of accommodation and recreational facilities in camps. The traditional canvas tents could now be used only temporarily and not at all in winter; men were normally to be housed in huts with bunks and fireplaces, and provided with bathing facilities with hot water, wash-houses, drying rooms and privies. Single men should have a 10 × 8 feet hut with fireplace, mattress and stretcher, while married couples without children should additionally have a 24 × 12 feet bed-sitting-room and 10 × 9 feet kitchen. Those with four children should have two bed-sitting-room units and a kitchen complete with attached bathroom and laundry. Where more than twenty men were employed, a recreation hall should be provided. Coates stated that 'in order to ensure a contented and efficient body of employees every

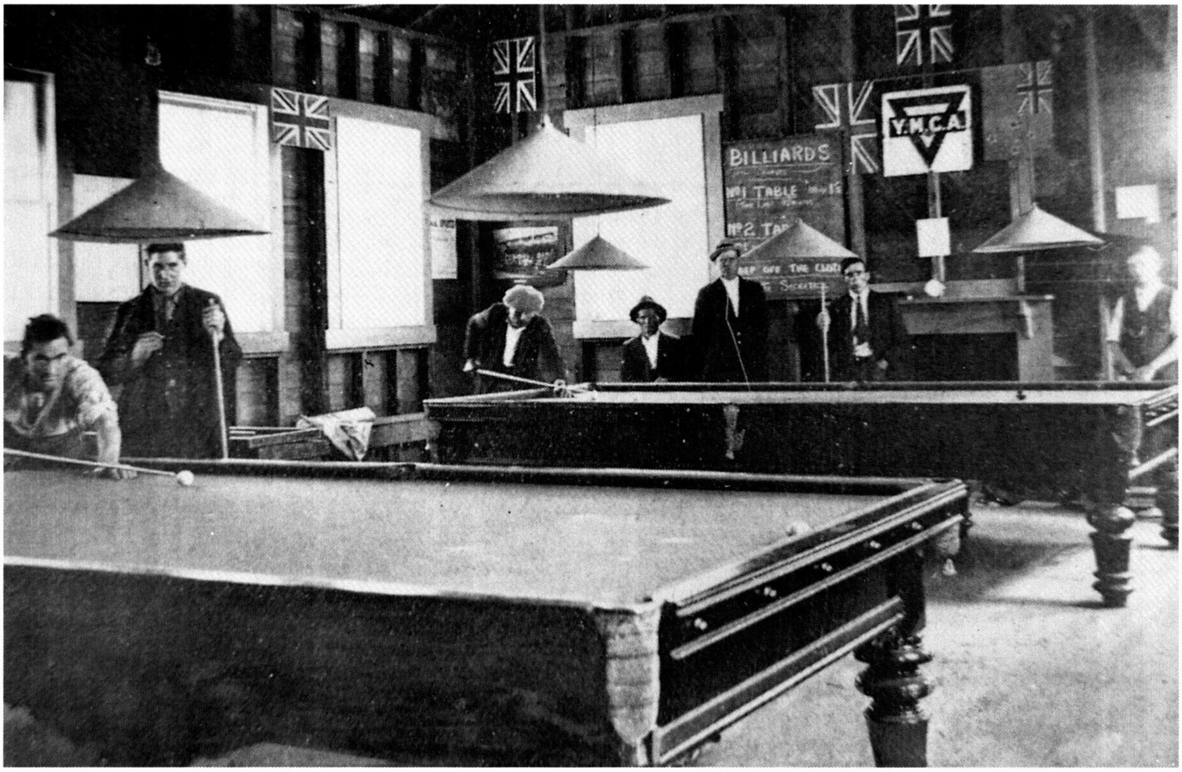


Lawrence Birks was born in Adelaide in 1874.[1] He studied engineering in Adelaide and gained a scholarship to University College, London, from which he graduated with a BSc in 1897. In 1898 he was Assistant Professor of Engineering at Heriot Watt College, Edinburgh. He received his practical training with Easton, Anderson and Goolden of Erith and Callenders' Cable Construction Company. From 1900 to 1903 he was assistant engineer for the New South Wales government for the construction of Sydney's electric tramways. In March 1903 he was appointed Christchurch city's Electrical Engineer. He also lectured in electrical engineering at Canterbury University College. In August 1905 he became engineer and manager for the company constructing Christchurch's electric tramways. From 1906 to 1910 he was Engineer-in-Charge for the Tourist and Health Resorts Department town of Rotorua. In 1910 he was transferred to Wellington to prepare a report for the government on the potential usage of and demand for electricity, and the best means of satisfying future demand. This key document was a manifesto for development. With the appointment of Evan Parry as Electrical Engineer in the Public Works Department, Birks in 1911 became his principal assistant. In 1913 Birks moved to Christchurch, where he took over supervision of the Lake Coleridge project and the selling of electricity to consumers, with brilliant success. His particular strength was, in his own words, 'the popularizing of electricity as a general domestic agency'. When Parry resigned in 1919, Birks returned to Wellington and took over as Chief Electrical Engineer for the Public Works Department, which he remained until his death. When he fell ill in 1924 he was unable to travel overseas to give the paper on the development of electricity in New Zealand that he had prepared for the first World Power Conference. It was appropriate that the paper was delivered on his behalf by Parry. Lawrence Birks was a member of the Institutions of Electrical Engineers, Civil Engineers, and Mechanical Engineers, and of the New Zealand Society of Civil Engineers. He died on 25 July 1924.

effort is now made to properly house and provide for the comfort of the men. Collapsible huts, amusement-halls, and YMCA canteens have been erected at some works, and others are being arranged.'[3]

The YMCA was to play an important role in the public works camps. During the First World War the organisation had provided recreational activities for New Zealand troops. In 1920 it was invited by the government to provide similar facilities in the construction camps. Mangahao was the first example of this approach. The YMCA provided equipment and organisers for the recreation halls erected by the Public Works Department. The halls were used by the New Zealand Workers' Union for its meetings and by various clubs and organisations, as well as for Sunday church services, which were conducted by the YMCA secretary if no-one else was available. More radical delegates of the Workers' Union were very suspicious of the motives of the YMCA, regarding it as 'a subtle means of perpetrating capitalism' and as 'opposed to Labour'.[4] They wanted the men in the camps to develop their own, union-based recreational organisation. However, it appeared that the men themselves were happy with the existing arrangements and the issue died.

Activity in the Hydro-electric Branch was still restricted by the labour shortages caused by the post-war expansion of business activity. By 1921 the end of the post-war boom and restrictions in



In the 1920s, under a new progressive Minister of Public Works, J. G. Coates, the working and living conditions of men employed on railway and hydro-electric construction began to improve. The YMCA was invited to provide recreational facilities for public works camps, and did this for the first time at the Mangahao scheme. YMCA recreational halls usually contained a canteen, reading room, and, as shown here, a billiard room. Concerts, dances and films were organised, and religious services were conducted on Sundays. At one of the Mangahao camps, a teacher used one room to run classes for the children.
AJHR, 1924, D-1

government expenditure were slowing development. High interest rates and rising costs also hindered progress with schemes. Coates announced that 'it has now been decided as inadvisable to proceed with the active construction of the whole of these works at the present time'.[5] (Parry had estimated that costs would be no more than 12 per cent higher than those before the war, whereas the figure was in fact about 50 per cent.)

Nonetheless, the department continued quietly with preparations. Surveys were in progress at Lakes Hawea and Wanaka, and the Teviot River. Diversion works had been started at Lake Coleridge. The construction of the Mangahao scheme was under way, investigations for the Arapuni dam were nearly complete, and the Hydro-electric Branch was poised to begin the complex Waikaremoana scheme.

Mangahao

The first scheme in Parry's plan was at Mangahao, north of Wellington.[6] The Mangahao River rises high in the Tararua Ranges, its natural course taking it northwards to the Manawatu River on the eastern side of the Manawatu Gorge. However, its route was very close to the western watershed. Its potential had been noted from the turn of the century: Hay did not consider it in his report of 1904 because of a lack of information, but he suggested that it should be examined in the future.

Hay himself soon investigated Mangahao. After surveys, he put forward in 1906 some five options involving diversion to the western (Horowhenua) side of the mountains, calculating that 10,000 hp could be developed. In 1907 a Palmerston North Borough Council surveyor proposed development of the Mangahao further downriver. Local-body members meeting in Shannon in February 1911 visited the site and urged further assessment of the project.

F. T. M. Kissel devised a scheme that adopted one of Hay's options, except that tunnels were

George Pellew Anderson was born at Wanganui in May 1882.[7] He graduated with a BE from Canterbury University College in 1905. His early practical experience was as a draughtsman in the Railways Department and as an assistant to an hydraulic engineer. In 1916 he joined the Hydro-electric Branch of the Public Works Department as an Assistant Engineer. In the period 1916–18 he surveyed the Mangahao, Waikaremoana and Waikato River sites and surveyed transmission line routes from Horahora to Auckland and for Mangahao and Waikaremoana. He was then in charge of part of the construction of Mangahao. In 1924 he went to head office, where he rose to become Design Engineer in the Hydraulic Structures Branch, and gained an unparalleled knowledge of water-power resources throughout the country, which provided the foundations for hydro-electric development. Anderson was largely responsible for the investigations and project planning for all schemes from that time, including extensions to Lake Coleridge, the Waikaremoana schemes, the Waikato developments, the Waitaki and Roxburgh schemes, and initial investigations of Manapouri. He retired from the State Hydro-electric Department in 1947 after making a major contribution to the assessment of the country's potential hydro-electric resources. He died in November 1948.

substituted for water races. His concept of diverting the Mangahao River to the Tokomaru River by way of tunnels proved feasible, although a lack of knowledge of river flows made calculations difficult. It was acknowledged that storage facilities were vital because of the extremely variable flow in the Mangahao River, and two reservoirs were included to this end.

The site was more promising than the Hutt River, hitherto considered for Wellington, and it was better placed to service demand northwards toward Wanganui. Manawatu was particularly anxious for supply. W. H. Field, the local MP, had earlier pressed the Minister of Works, Sir William Fraser, for details of Hay's report; he maintained this pressure during the surveys.

A survey party set up camp in 1915 at Arapeti, the headquarters of the Arapeti Land Company and the site of an old sawmill. In 1915 and 1916 they prepared contour plans of the Arapeti and Tokomaru basins before moving on to the Mangahao itself, where they identified possible dam sites and tunnel routes and made regular observations of river levels and rainfall.

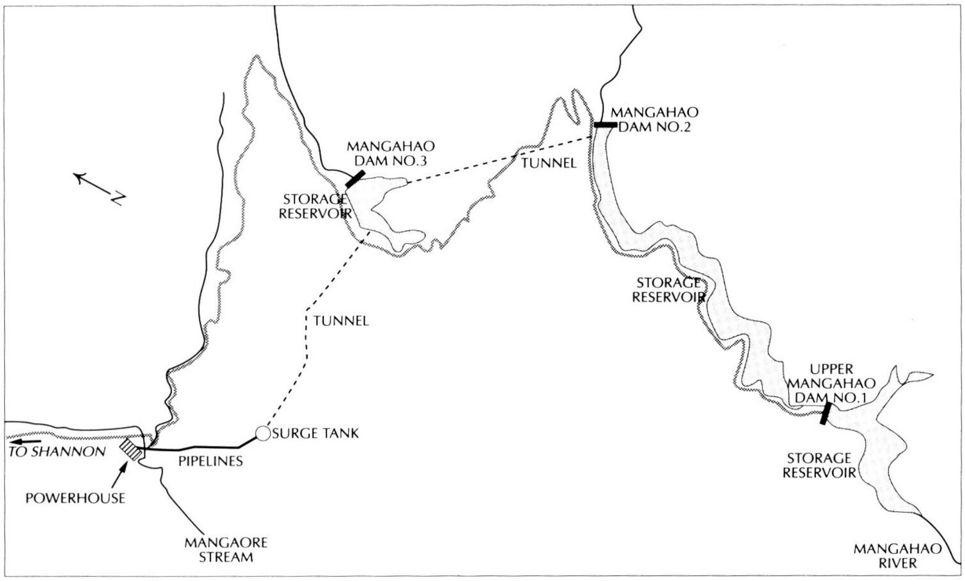
G. P. Anderson, Assistant Engineer for hydro-electric schemes in the Public Works Department, undertook transmission line surveys in 1917 and 1918, equipped with a travelling hut, two horses and two bicycles. He was responsible for providing road access — no small task in itself — and the infrastructure of the project.

Anderson surveyed the transmission line routes from Shannon to both Wellington and Wanganui, and into southern Hawke's Bay and the Wairarapa. He described such work as follows:

> The route is usually settled beforehand from maps and considerations of market. It may have to be modified to suit the natural features of the country, which may be rough, swampy, or subject to fogs or salt-spray . . . General location along a valley or a ridge or across a flat can usually be decided after a casual inspection of the country. It may be necessary, however, to run trial lines, and to take into account the cost of construction and facility of patrol, as well as length and mechanical and electrical features . . . Precise location entails the exact fixing of lines and angles and the spacing of poles so as to give the requisite clearance and to ensure stability under all conditions.[8]

Despite the lack of an official commitment to the project, preparatory work for Mangahao went ahead. Kissel, as assistant to Birks, was responsible for both the overall scheme and the power

Mangahao: Constructed 1920–24. (The No. 1 Upper Mangahao dam was constructed later in the period 1925–27.) Head 896 feet. Water is stored behind two concrete dams on the Mangahao River on the east side of the main ridge, and led by a tunnel to a third dam (Arapeti) on the Tokomaru River on the west side. The No. 1 dam is gravity/rock, 116 feet high and 774 feet long, while the No. 2 dam, also gravity/rock, is 104 feet high and 404 feet long. The No. 3 dam, gravity, 102 feet high and 430 feet long, is built higher than No. 2 so that the overflow goes back over the No. 2 dam into the Mangahao River. The tunnel from the No. 2 to the No. 3 dam is 5,290 feet long. The second tunnel, 7,060 feet in length, passes water from the No. 3 dam to a surge chamber. Two tapering penstocks run for 2,296 feet and then bifurcate for a further 1,497 feet to the powerhouse. One pipe bifurcates again at the powerhouse, to make a total of five penstocks, each driving a Pelton wheel. The Pelton wheels drive generators, three of 4,800 kW and two of 2,400 kW. Total capacity is 19,200 kW.



plant. By April 1917 the plans for the powerhouse near Shannon were complete and some roading work had been done. The potential demand in Wellington, the Hutt Valley, Manawatu, Wanganui and Wairarapa had been surveyed. Meanwhile members of various local bodies and chambers of commerce from Wanganui to Wellington visited the Mangahao site. The party of 46, together with two local MPs, travelled as far as the powerhouse site by car and then on horseback up into the ranges to the various sites. The amused manager of the Arapeti Land Company observed to Parry that 'the old track is not in the best of order for fat "politicians" to amble down'.[9] The group reconvened in Shannon for afternoon tea and a conference, at which a delegation urging approval of the scheme met the Minister of Public Works and Parry, without success.

The Mangahao Hydro Electric Power League was formed at a conference in Palmerston North in June 1918 to agitate for an immediate start to the project. Public meetings nagged at the Minister, who insisted that all must wait on Parry's full report. J. A. Nash, future MP for Palmerston North and for many years President of the Electrical Supply Authorities Association, finally succeeded in bringing Parry to Palmerston North to speak to the league. There Parry described his plan for the three stations, which was published in the Public Works annual report for that year. Soon after this, Parry resigned to return to London; it was his successor Birks who began to carry out his grand plan.

By late 1919 a road had been pushed through to the top of the Mangahao Valley, and work at the Mangahao site was being planned. From the road-end a double line of 'jig-way' dropped at 45 degrees the 500 feet to the valley floor. Everything needed for the Mangahao dam had to be delivered by jig. Anderson recorded a winter of incessant rain and endless mud as the contractors tried to make progress.

Because access through the steep and narrow gorges was difficult, camps were set up as close to the three construction sites as possible. Some married workers had to live in Shannon because there was no suitable accommodation for them on site. (Married workers comprised nearly a third of the work-force.) There was a rougher camp in the cramped Mangahao Valley itself housing (at peak) some 300 single men. This was perched on the side of the very steep valley, with the tents pitched on benched terraces. It was a

> frontier town . . . [with] none of the ameliorating circumstances which made Arapeti merely a township . . . . Here little softening influence penetrated, nor any social restraint to check the natural proclivities of what has been described . . . as 'the hardest collection of individuals to be found from one end of the North Island to the other' . . . . A strong hardy, rough crowd who worked hard, fought hard — many a Homeric combat was fought out round by round on the sand of the river bed — and when pay-day came, gambled hard. The Mangahao 'two-up' school was an institution.[10]

The Arapeti camp was more civilised, with four-roomed cottages for each of seventeen married men and huts for 84 single men, as well as tents. A teacher ran classes in the YMCA room. The third camp was at Mangaore, the site for the powerhouse. The camps included cookhouses, recreation halls, canteens and reading and billiard rooms.

The YMCA organised concerts and dances, and films twice a week, and the men also indulged in the leisure activities such as gambling and card games that were a strong tradition in public works camps. They were paid monthly after their cookhouse and canteen bills had been deducted. A host of salesmen would descend on the camps to sell the men anything 'from magazines, patent medicines and many types of foods, to suits of clothing made to measure'.[11] The 'Vigilance Committee' of the Mangahao League was not very enthusiastic about the site organisation, the rates of pay, or the resulting quality of the work-force — criticisms that G. P. Anderson agreed with.

Living conditions at Mangahao were abysmal because of the frequent heavy rainfall and the difficulty of access. There was rain on about 200 days each year, clothes were impossible to keep dry and were constantly mildewy, mud was everywhere, and the men had to work in the rain much of the time. MPs who visited the camps in 1920 reported 'men living in tents in the heart of the bush without floors or fires, slushing about in the mud and the muck and with no provision for drying clothes. Their meals were provided by private enterprise in a low smoky tent in which there was a slab table with a rail to sit on.'[12] While the single men made do with 10 × 8 feet tents, married families at this time usually lived in two tents of this size back to back, with flooring and low walls. This allowed for a bedroom, a kitchen and a covered porch between the two tents. A fireplace with a raised hearth and a corrugated-iron chimney would be provided at the end of the kitchen tent.

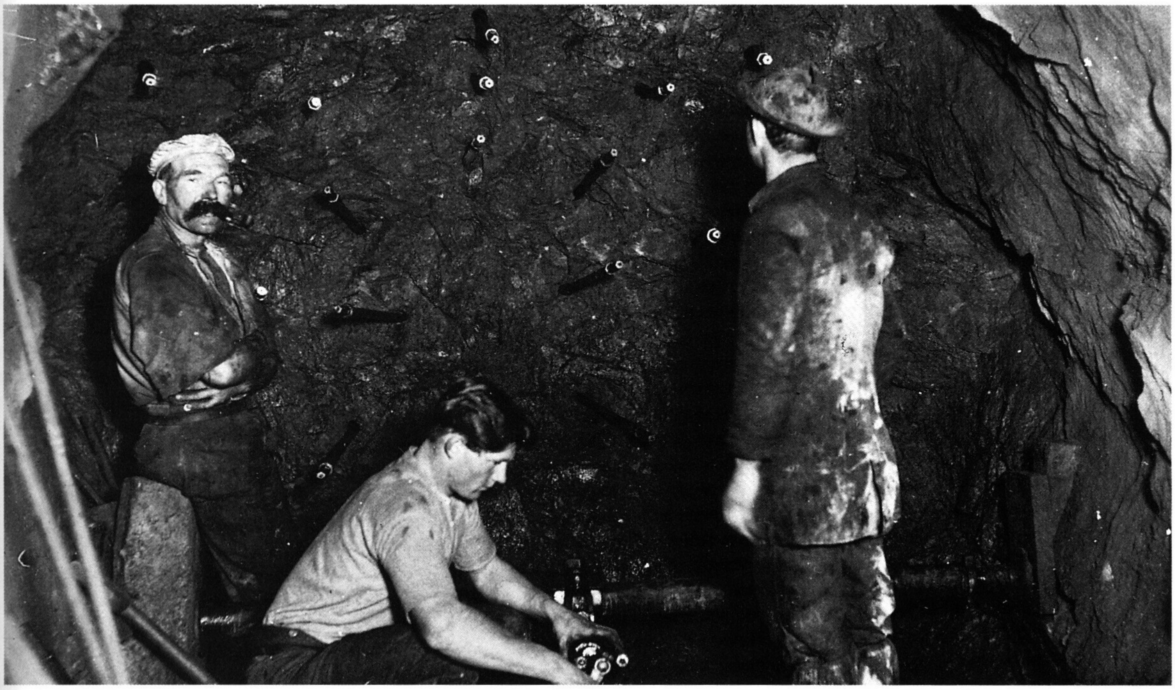
In 1919–20 testing for dam foundations was carried out. It was necessary to obtain as much of the construction material as possible on site. Not only were there transport problems, but there was an acute shortage of timber. As a result, a complete milling plant was brought in to produce sawn timber for both staff housing and formwork for the concrete. By May 1920 most of the access road had been completed, the sawmill had started production, and excavations for the Arapeti dam and the penstocks had begun.

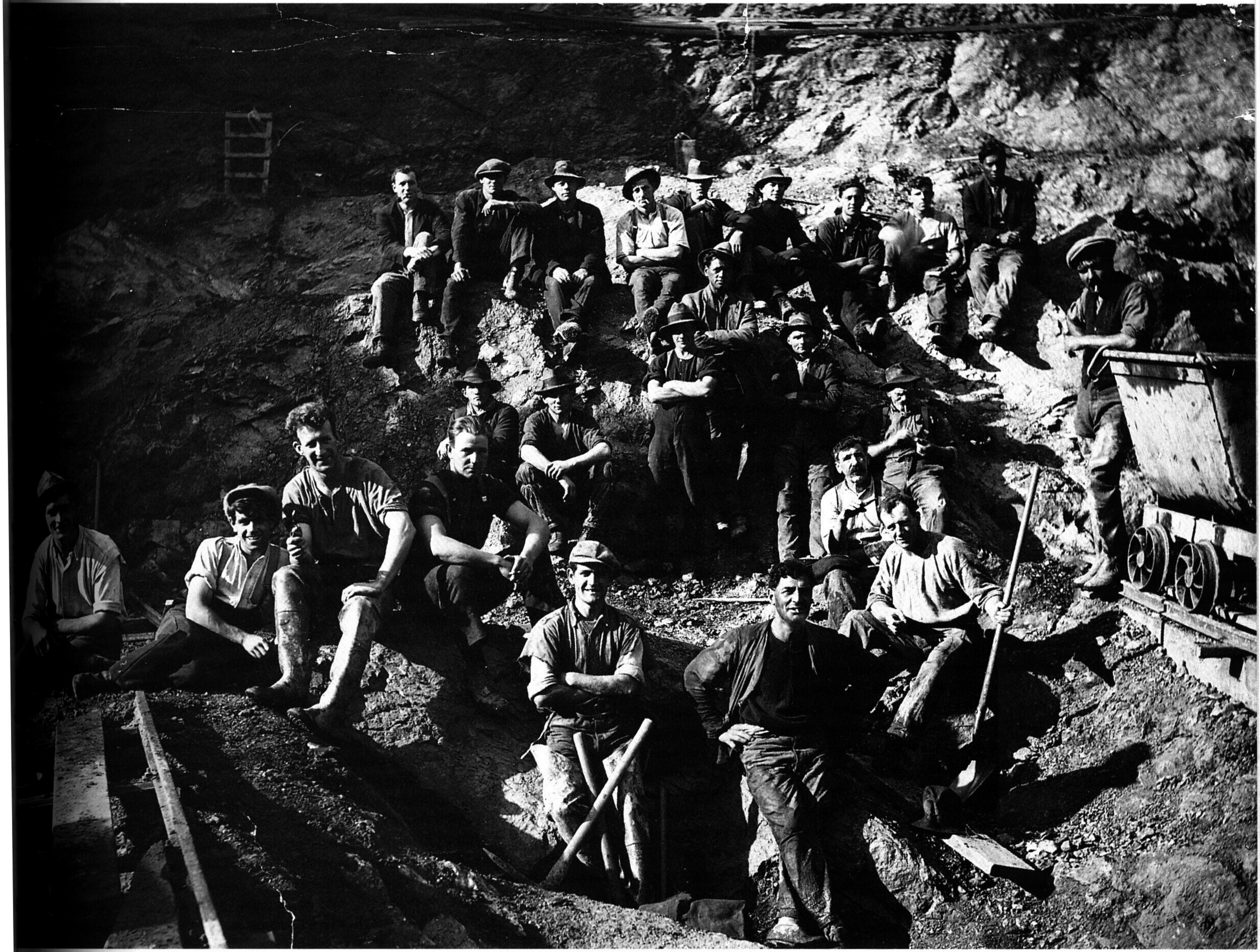
As F. W. Furkert, Engineer-in-Chief of the Public Works Department, reported, 'everything possible at the dam[s] was done mechanically', in line with Coates' new policy.[13] A substantial steam-powered electricity generating plant was built on site, quarrying and tunnelling was done with compressed-air drills, and where possible, electric battery-powered and petrol-driven trains were used to move spoil and materials.

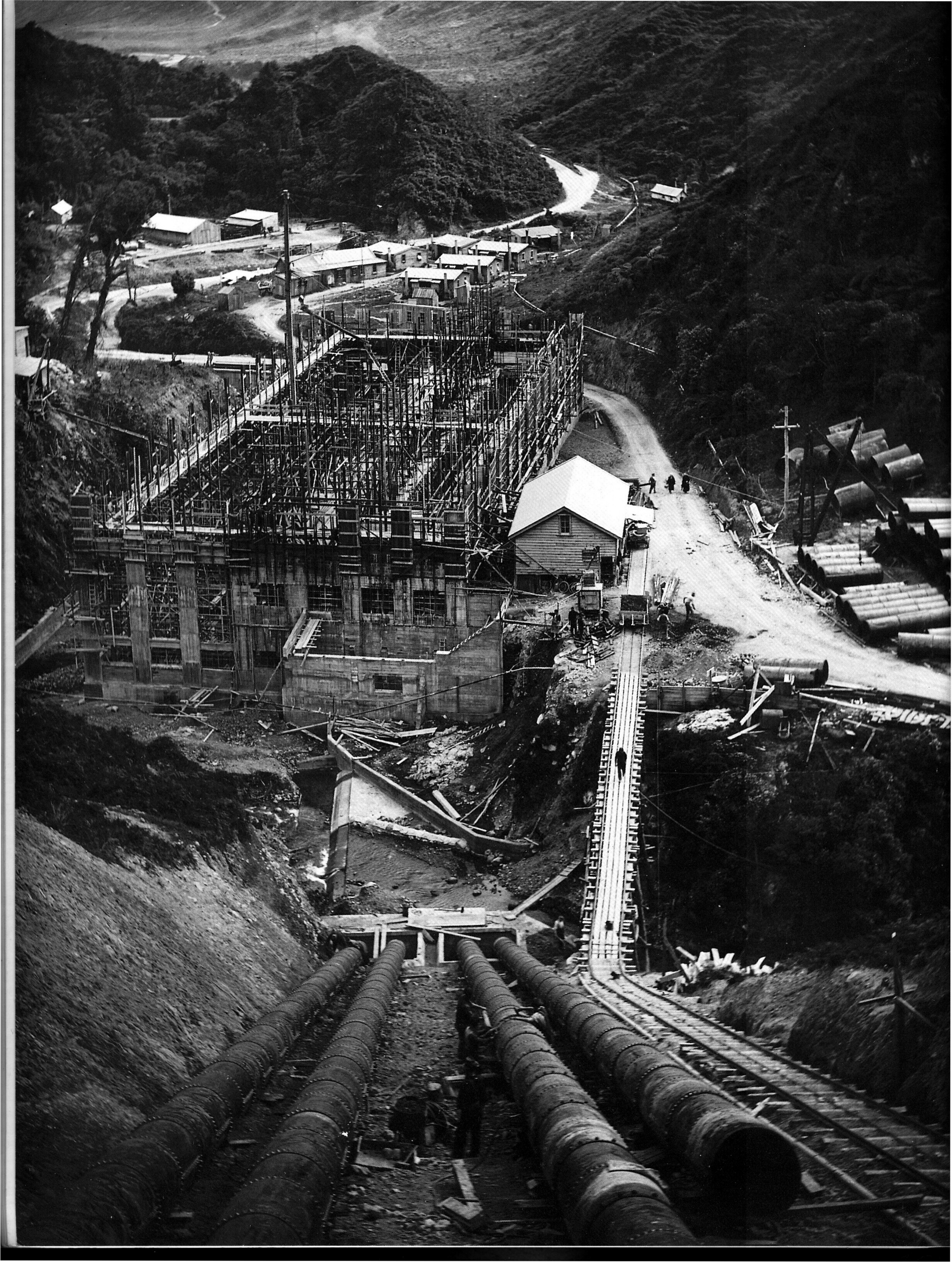
By mid-1920, some 180 men were employed on bush-felling at the Mangahao dam site. Work on the No. 2 tunnel from Arapeti to the surge chamber began in January 1921, and on the No. 1 tunnel from Mangahao to Arapeti in March 1921. The tunnels were driven by May 1923 and

Opposite above: Drilling to place charges in the inlet of the No. 1 Mangahao tunnel, which ran from the Mangahao River to the Arapeti dam. When a tunnel was being driven, holes would be drilled in the face and charges placed in a carefully defined pattern to remove the appropriate section of rock.
AJHR, 1921, D-1

Opposite below: A work gang at rest, Mangahao project construction, *c.* 1922.
Adkin collection, National Museum







then lined. Progress was hindered for a time by a strike by the co-operative contract gangs. (The co-operative contract system was used extensively for public works from the 1890s onwards. It maximised the use of labour and was particularly suited to straightforward labour-intensive construction work that could be broken up into many small contracts. The men shared equally in the wages earned, which were based on the estimated value of the contract.)

Meanwhile excavation for the dams, surge chamber and pipeline was taking place, and transmission lines were being built. The powerhouse was begun in April 1922, by which time the surge chamber and pipeline were almost complete. The Mangahao dam diversion tunnel was started in June 1922 and finished a year later.

At first the men worked only an eight-hour day, then two shifts were introduced, and by February 1923 three shifts covered the full 24 hours, with the sites lit by arc lights. By this time nearly 900 were employed on the project, compared with 340 the previous June.

Most effort now went into building the dams. The distinctive geological nature of the sites made dam building more difficult than had been expected, especially at Mangahao, where it was discovered that what appeared to be a solid rock wall on one side of the gorge actually hid a previous river channel packed with boulders and rubble. The dam had to be extended considerably as a result and, rather than a concrete arch, it became a gravity dam with a section of concrete core-walled earth-fill where the boulders were. The dam, begun in November 1923, was built with a 40-foot gap in the centre to allow flood waters to pass through. Automatic tilting gates on the spillways were a novel feature in New Zealand. They formed two wide passages for water during floods, but were designed to return to position as levels dropped, thus retaining as much water as possible. Because of problems, the design of the Arapeti dam was changed from an arch to a gravity arch. By early 1924 the Mangahao dam was almost complete, and the Arapeti dam, after some difficulties, had bridged the river.

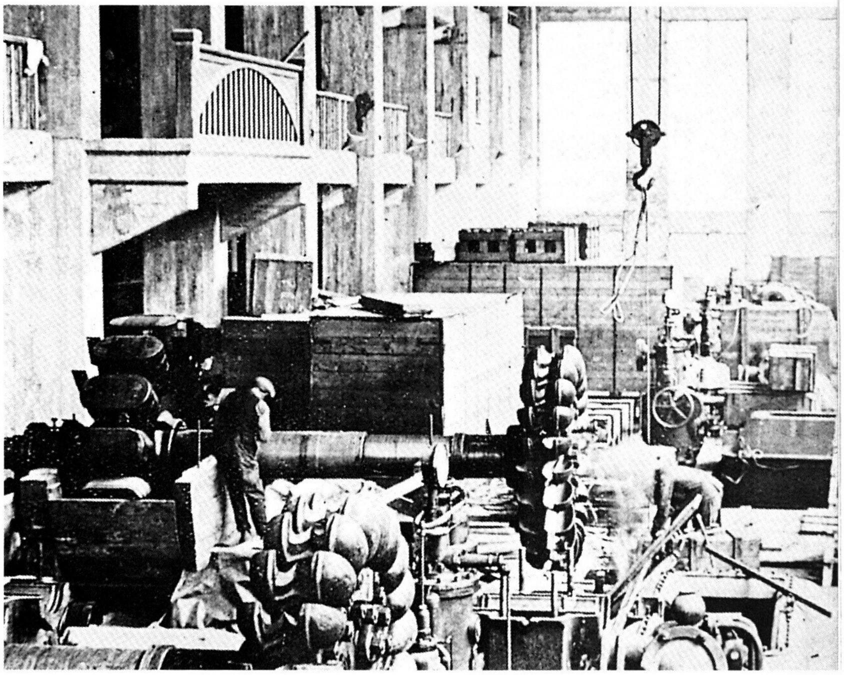
Diversion and dam works were hindered by frequent and sudden flooding, which time and again overwhelmed and levelled the temporary coffer dams, delaying construction by six months. The river's usual flow was 80 cusecs, but in peak flood conditions during construction it reached as high as 18,000 cusecs. Despite the dangers, no lives were lost in dam construction, although 'the work was inundated by floods repeatedly, often with hardly any warning, so that men sometimes barely escaped with their lives'.[14] Floods were a fact of life at Mangahao, occurring virtually weekly. In January 1923 there were 24 days of rain, and in one flood the water level at the dam rose at a rate of six feet per minute.

Opposite: Constructing the penstocks and powerhouse at Mangaore, near Shannon, Mangahao project, *c.* 1922.
Adkin collection, National Museum

There were a number of fatalities in the No. 2 tunnel. In one incident an unexploded charge, struck by a shovel, killed one man and injured another. A second accident, on 2 July 1922, was much more serious. Carbon monoxide generated by a faulty tunnel pump engine was not discharged through the ventilation system, and two tunnellers were asphyxiated initially. Another five who tried to go to their assistance, including the Engineer-in-Charge, were also overcome by the gas.

By 1924 the powerhouse had been built and machinery was being installed, and that September the gap in the Mangahao dam was closed. This was done in a great hurry to raise it above flood level. Even so, several floods swept through the gap as it was being built.

Installing generator rotor and Pelton wheel assemblies in the Mangahao powerhouse.
AJHR, 1924, D-1



> An atmosphere of haste pervaded the valley. On the gap itself, where a score of men in gum-boots stood to the knee in the wet concrete, which they shovelled as the chutes shot it down to them from the mixers above, there was feverish haste . . . over all there appeared to be constant watchfulness. Somewhere above in the bush-clad valley was the flood, an enemy whose powers were well known, and frantically they strove to erect a wall against his certain coming. Day and night the work went on, one set of men, well-fed and rested, taking up the shovels of the preceding gang, ever building higher against the common foe.[15]

The Prime Minister, William Massey, opened the Mangahao station on 3 November 1924. Transmission to Horowhenua began that month, and coverage was gradually extended to Wellington and other districts. This was the first instance of 110 kV transmission in this country. In all some 300 miles of 110 kV line were built, with duplicate lines running the 63 miles to Wellington. Consumers in the region, particularly dairy farmers, dairy companies and flax mills, took advantage of this new source of power straight away.

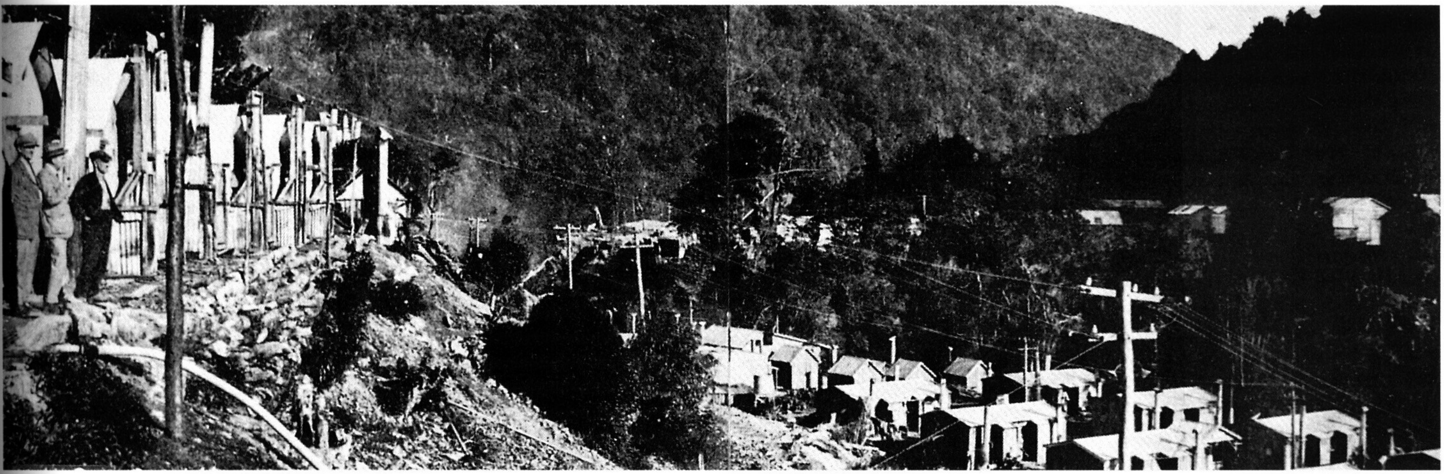
The creation of power boards for the area had become a matter of some urgency as the commissioning of Mangahao neared. Birks worked hard to bring the local authorities together. In 1920 he attended conferences at Feilding and Levin, while Coates visited Palmerston North to hear the arguments and urge the importance of settling boundaries and completing reticulation. This proved easy in Horowhenua, but extremely difficult in the Manawatu. The government's preferred option was for Palmerston North to join the others in one large scheme, but the town had reached agreement with neighbouring Kairanga County, which did not give the desired rural/urban mix. The rival centre of Feilding proposed combining only with Manawatu County, which for its part wanted to link with Horowhenua. The Minister would not agree to such arrangements. While not prepared to dictate, he urged the formation of districts of an adequate size. At a meeting in June 1921, chaired by Coates, agreement was reached for a combined Manawatu-Oroua Power Board, which took in both urban centres and surrounding rural districts and conformed largely to the boundaries the government had proposed originally.

Meanwhile other recently formed power boards which were to be supplied from Mangahao were unhappy. The Hutt, Petone, Tararua, Wairarapa, Horowhenua and Dannevirke boards were all reluctant to spend money on reticulation, or to agree on the minimum amount of power they were required to take, until the date when Mangahao power would be available was certain. They also regarded the proposed charges as too high to attract sufficient customers.

In the event Mangahao was stretched to meet the demand. All power boards in the area served soon exceeded their original guaranteed loads, some doubling them. By the time lines reached Napier in 1927, the plant was overloaded. The government was now criticised for deciding to build at Mangahao first. The station had been all too successful in creating a demand that could not be easily met until the Waikaremoana project was completed, which was now scheduled for 1929. The fundamental problem was that Mangahao could not really operate as a base-load station; it was more fitted to the role of a regulating seasonal water-storage station utilising the frequent floods. Little run-of-river power and limited storage was available.

In 1925 work began on the construction of the No. 1 Upper Mangahao dam, also with tilting gates, which would increase storage capacity nearly three-fold. Mangahao would then be able to run at full load for about seven days if all reservoirs were full. A road was built upriver and a new camp for several hundred men was erected, with single men's tents, huts for both single and married men, three bathhouses, a large cookhouse, a YMCA hall and a school. The total population of the camp was close to 500. It was reported that 'the activities of the YMCA, which is subsidized by the Department, have made a wonderful difference to the life of this isolated camp, and give both the men and their families a marked social interest, which has tended to retain a better class of workmen'.[16] An important development was the first system of medical insurance in a public works camp, which was operated by an elected 'medical association'.

Excavation of the dam site proceeded, and a diversion tunnel was driven by working three shifts a day and seven days a week. The dam had been finished by the beginning of 1928, but a severe drought delayed its filling until April. Power cuts had to be imposed in the region because Mangahao could not cope. By January both existing dams were virtually exhausted. Power boards were asked to restrict load, and there was a general request for all centres in the

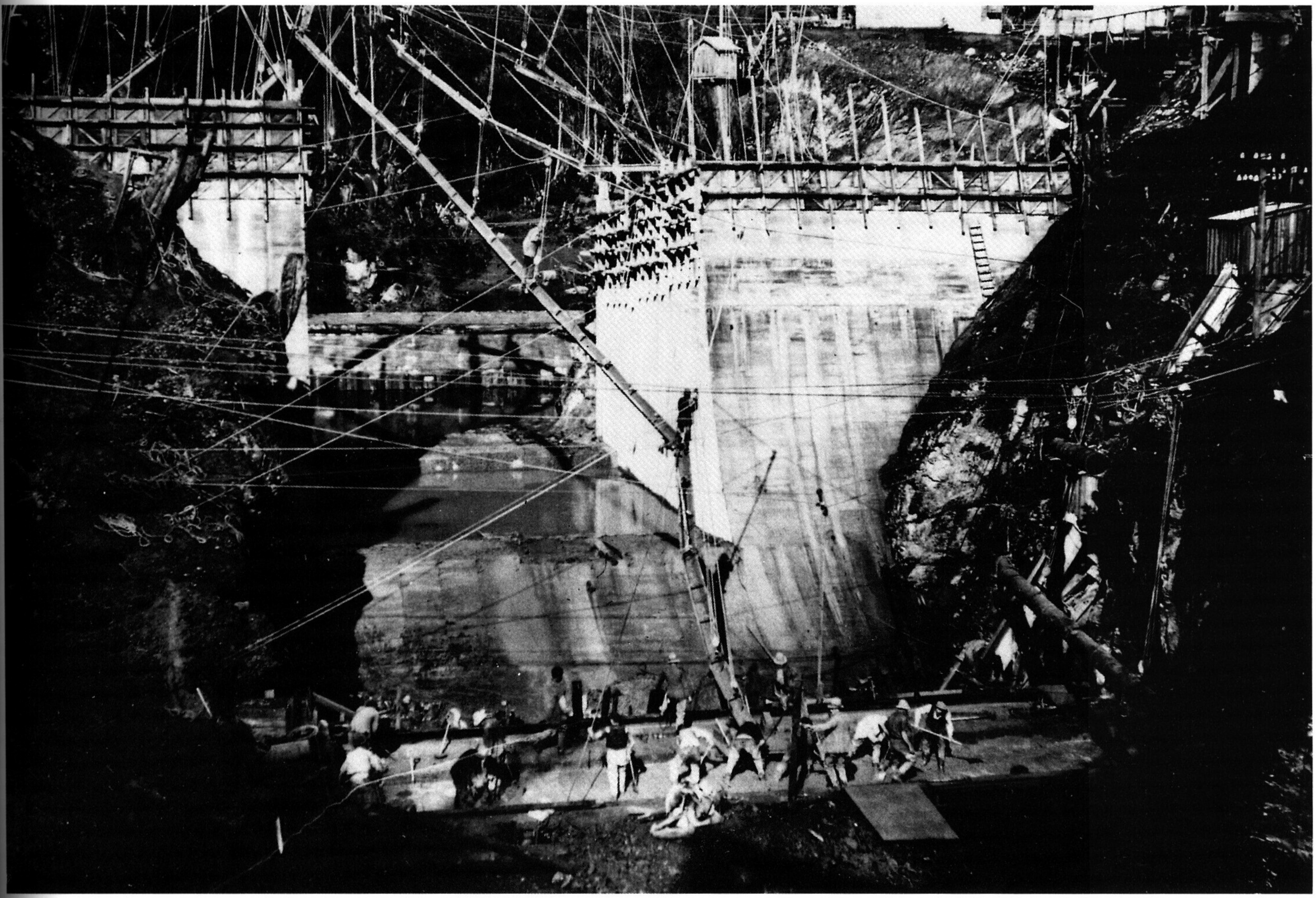


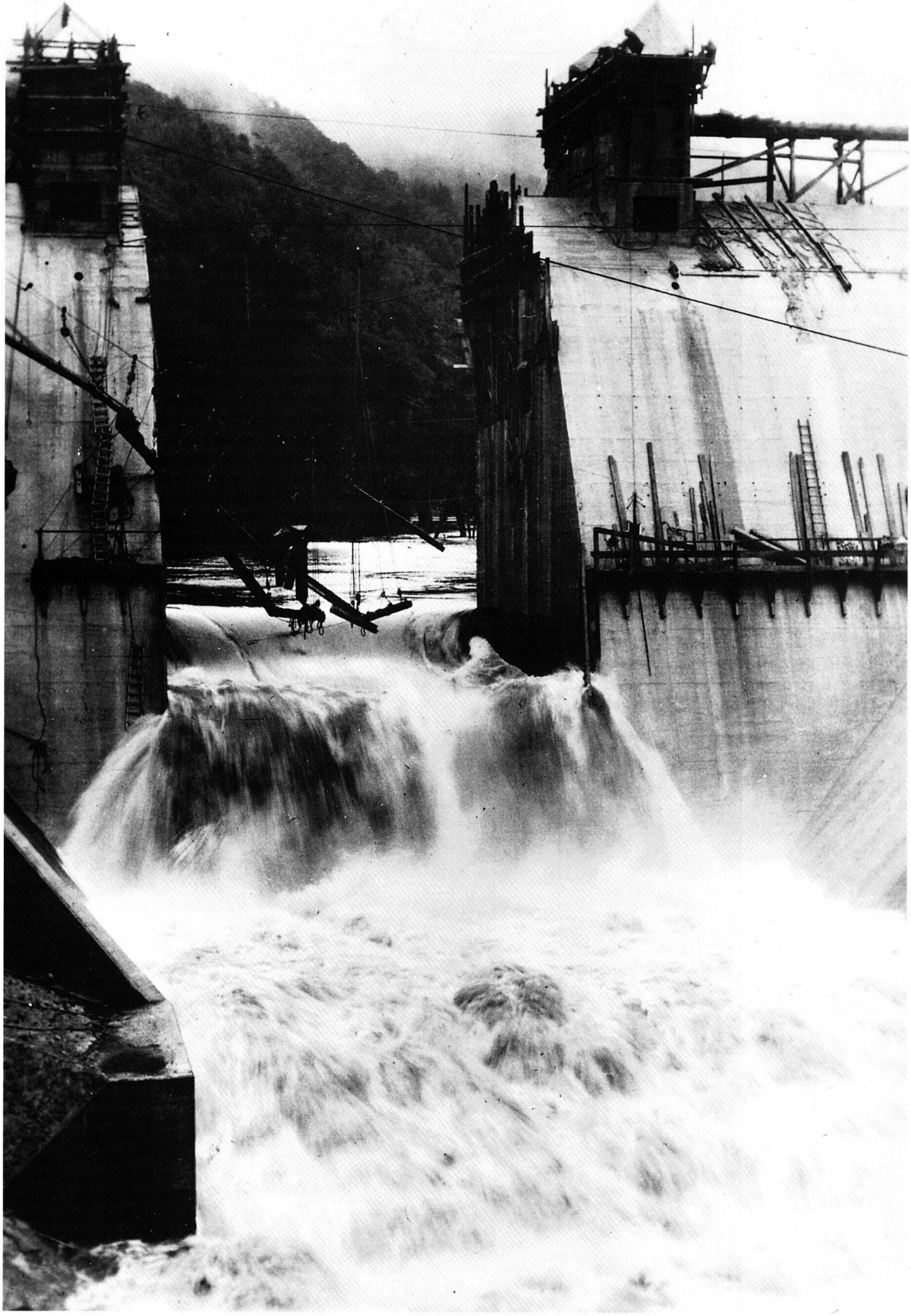
Above: The camp at the No. 1 Upper Mangahao dam, showing rows of huts on benches on the precipitous slopes above the river. At left are the single men's 10 × 8 feet huts, with larger, married men's huts and other buildings at centre and right.
AJHR, 1926, D-1

Below: Construction of the No. 1 Upper Mangahao dam, with men working on the toe at its base. Also shown is the complex network of wires, ropes, pulleys and channels used to deliver concrete.

southern half of the North Island to activate any available auxiliary plant, as well as the plants belonging to freezing works, flax mills, etc. Wellington city relied upon Evans Bay and recommissioned the old Harris Street Curtis turbine.

With the filling of the new storage reservoir at Mangahao, and the subsequent commissioning of the first unit at Tuai (part of the Waikaremoana scheme) in February 1929, the situation in the lower North Island eased.





The Mangahao scheme involved damming the Mangahao River, which frequently flooded in spectacular fashion. This created considerable difficulties. Here water pours through the unfinished central section of the No. 1 Upper Mangahao dam, built between 1925 and 1927.

Arapuni

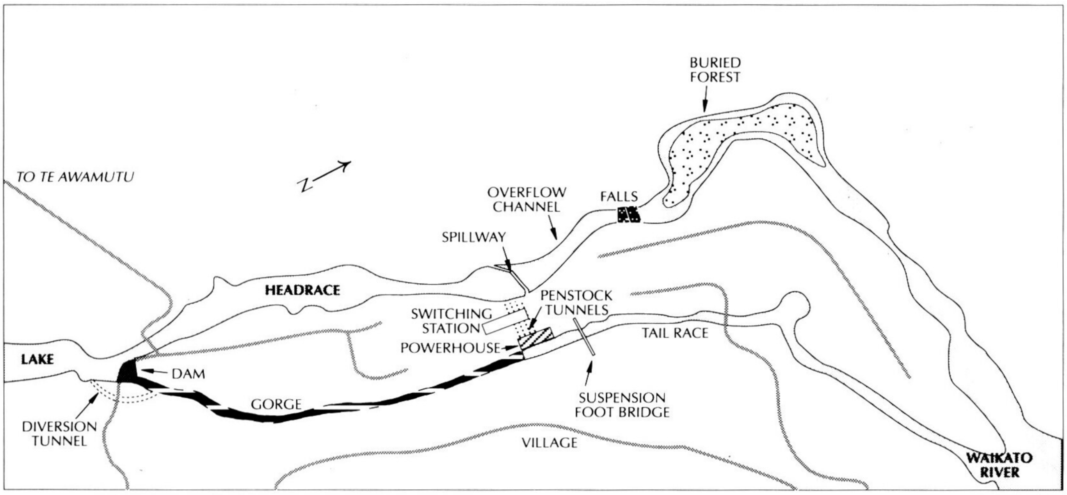
Apart from the private scheme at Horahora, Arapuni, an obvious and attractive site, was the first development of the Waikato River.[17] By the mid-1960s, when the Waikato was fully developed, it produced nearly half of New Zealand's power. The exploitation of the river was to involve a chain of stations, mostly in narrow gorges. There were considerable technical problems to be solved because of the faulted and jointed rock, which caused leakage and instability and made conditions for foundations difficult.

Arapuni, the next scheme after Mangahao in Parry's plan, was controversial from the outset. By the standards of the day it was massive indeed. The Waikato River above Cambridge had been surveyed in the years 1916 and 1917, and surveys were also made of transmission line routes from there to Auckland. The site for Arapuni was a deep and narrow rocky gorge, six and a half miles upriver from Horahora. An old river channel, parallel to the modern one and well above it, provided a natural headrace. A dam could be built to divert the river into the old bed and down a channel to a forebay, with the water dropping through penstocks driven down through the wall of the gorge to a powerhouse on the river. Surplus water could continue along the old channel and eventually back to the river.

However, the geology of the area was suspect. The Public Works Engineer-in-Chief, R. W. Holmes, therefore urged a careful comparison with possible projects on the Kaituna River or at the Aratiatia Rapids. The Kaituna River possibility, at the outlet from Lake Rotoiti, would have been extremely expensive and was never investigated. Aratiatia was ideally situated in a theoretical sense, since it was near the centre of the entire North Island load. If water was backed right up into Lake Taupo — with the Huka Falls drowned in the process — a fairly large station could be built. But the site was inaccessible, the dam would be more expensive than one at Arapuni and the output less, and the transmission distance to Auckland was much greater. A decision was made to concentrate investigations on Arapuni.

From the beginning there were exhaustive geological investigations. In 1917 a geological report on the Arapuni Gorge was prepared. In early 1919 shafts were sunk and a tunnel driven under the river to assess the stability of the dam foundations and abutments. Numerous rock samples were sent to Wellington for tests of porosity and

Arapuni: Constructed 1924–29. Head 175 feet. Water is directed from an arched concrete gravity dam, 210 feet high and 308 feet long, into a ¾-mile-long headrace which had been formed in an ancient elevated watercourse. This leads to the intakes for eight concrete-lined penstocks driven down through the wall of the gorge, which are approximately 450 feet in length. The water drops to the powerhouse in the gorge beside the river. Eight turbines and generators were installed in stages, the first four in the period 1929–32, two more in 1937–38 and the last two in 1945–46. Total capacity is 158 MW.



compressibility; these suggested that the rock was adequate for a dam.

However, in 1920, when it appeared that work at Arapuni would soon begin, Birks briefly considered something very different: encouraging Auckland city to build a coal-fired station at Huntly that would supply the whole area between Te Kuiti and Helensville. But Auckland did not want the government diverted from Arapuni. In August 1921 Coates announced that Arapuni would go ahead — once the financial situation had improved.

The long delay in announcing a start on Arapuni caused much anxiety in Auckland, anxiety that had intensified after the government's purchase of Horahora in 1919, when it was realised just how little of the city's thirst for power that station could assuage. Horahora power was not really available for Auckland anyway — or not at times when most people wanted to use it — and there was little even for the towns between the station and Waihi. The extensions at Kings Wharf would not be ready until 1923, and these would not in any case weaken the perceived grip on Auckland of the coal miners. Considerable pressure to begin work at Arapuni was brought to bear on the government.

Coates continued to assert that the scheme must wait until the economic situation improved. Money was tight, and the government was retrenching in every possible area. He again raised the possibility that Auckland might put a plant on the Huntly coalfields, which could use the line that was being built to take surplus night power north from Horahora.

In 1922, as preparations were being made for construction to begin, Furkert recommended that all work at Arapuni be stopped. Coates, who wanted to lure Auckland into a contract to take power from Arapuni, did not accept this recommendation. His goal was to stop Auckland deciding to go it alone and so obtain the income that would assure the project's financial viability. By the end of 1922 he had his contract, and had undertaken to supply power from Arapuni from 1928. The Auckland Electric Power Board, formed in 1921, had guaranteed to take a minimum of 15 MW. In the meantime Horahora would help meet Auckland's needs.

Coates' annual report in 1923 looked more optimistically at future hydro-electric development and set out plans for the next six years. These encompassed expenditure on the completion of Mangahao, the construction of Arapuni,

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Frederick Templeton Mannheim Kissel was born at Templeton in 1882.[18] After graduating with a BSc from Canterbury University College in 1905, he joined the Public Works Department and was involved in railway construction. He then became Engineer for the Selwyn County Council, but in 1911 was reappointed to the department as Engineer-in-Charge of the construction of the Lake Coleridge project. From 1915 he worked on North Island investigations as Office Engineer in Wellington before being promoted to Assistant Chief Electrical Engineer. After making one of the first trips overseas by a Public Works Department officer, in 1922, to study the latest advances in hydro-electric engineering, he was appointed Chief Electrical Engineer after Birks' death in 1924. Upon the formation of the State Hydro-electric Department in 1946, he became its first General Manager. He retired in 1948, having overseen the emergence and development of New Zealand's electrical system through the Depression and the Second World War, and into the modern era with a separate department of state responsible for electricity generation. He died in Wellington in July 1962.

extensions to Horahora and Lake Coleridge, and a start on Waikaremoana. About £1 million per annum was budgeted for.

There had been a technical as well as a financial reason for delay. Kissel wanted a gravity arch dam in which there would be some horizontal thrust against the walls of the gorge. Others, fearing that the walls were too soft, argued for a straight gravity dam that would depend only on downward thrust. This difference of opinion became public, and Birks had no option but to refer the issue to a committee of engineers, which in April 1921 recommended an increase in the amount of concrete sufficient to make it in effect a gravity dam, even though it was arch-shaped.

Because of a belief that the project would be too large and difficult for the Public Works Department to cope with, much of the construction work was to be given to an overseas contractor. The contracts for the dam and diversion works and for the powerhouse and generating plant were advertised together because of a wish to engage only one contractor. The combined contract was let to the lowest tender, from the English firm of Sir W. G. Armstrong, Whitworth and Company and included a considerable component of Swedish plant. New Zealand engineers had a strong preference for Swedish generators, transformers and switchgear. The station would initially comprise four 15 MW units.

Following the death of Birks in 1924, Kissel took over as Chief Electrical Engineer. Arapuni was to be a considerable test of his abilities.

The Public Works Department made good progress on roading, bridges, the village site, houses, and the construction of transmission lines and substations northwards. The 105-mile 110 kV line to Auckland was completed in 1925, and lines were also extended into the Bay of Plenty.

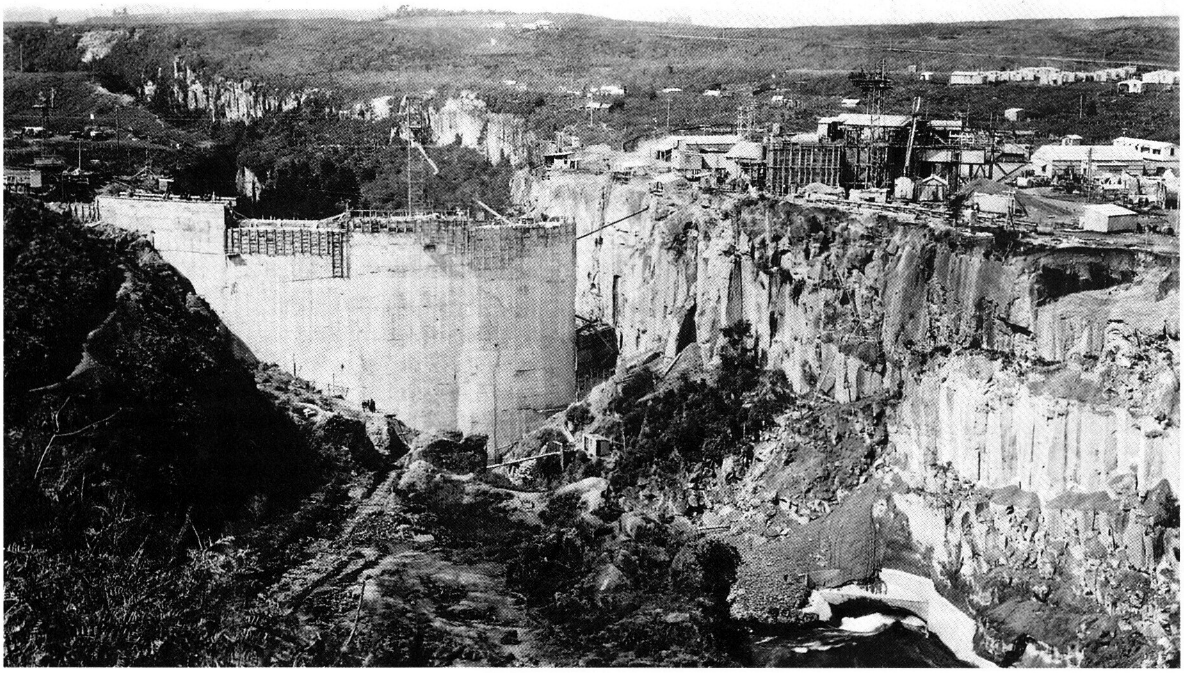
Two camps accommodating some 600 to 700 workers were built; their total population in 1926 was about 850. The 'top camp' was for those constructing the spillway, penstocks and outdoor transformer station. Access to this camp was by means of a long suspension footbridge across the gorge which is still there. The 'bottom camp' or 'damsite', a mile upriver, housed those building the diversion tunnel and dam, and had a post office, general store and recreation hall. Each camp had some 50 to 60 married men's huts of the by-now-standard specifications, and a long barracks comprising some 200 10 × 8 feet cubicles for the single men, as well as cookhouses and bathhouses.

A cottage hospital and medical association had been established by 1925, but these became successful only after a system of regular deductions from pay was instituted.[19] Each member of the association contributed 1s per week in return for free medical care. In 1928 the Waikato Hospital Board took over this service from the association. In 1925 a large recreation hall with accommodation for 400 people was built, and used for dances, concerts and movies. In 1928 the workers decided they wanted their own hall, and it was agreed that if the department supplied the materials they would build it with voluntary labour. The 'Workers' Hall' became the centre of social life in the camp.

In late 1924 work began on the 720-foot concrete-lined diversion tunnel and excavations for the powerhouse, headrace and dam site. The contractors concentrated on the diversion tunnel, which was driven into the solid rock of the gorge to take the full flow of the river. Severe floods in 1925 and 1926 caused damage and slowed work on the diversion tunnel, and when the construction workers struck for a week over overtime payments, progress was further delayed. The diversion tunnel was completed in July 1926, and by October the dam site was dewatered.

Work on the dam then began in earnest and good progress was made, but the powerhouse was another matter. When the contractor began excavating the foundations with the river still running past the site, it seemed impossible to create an effective coffer dam to prevent river water entering the excavations. The contractor declared the site unmanageable and work ceased. Nothing was done on the site in 1927.

This created a full-scale dispute, with the government asserting that the contractor had realised early on that it had made a major blunder by tendering so low. On its side, Armstrong Whitworth argued that the department had chosen an impossible site for the powerhouse. By July 1927 Furkert was contemplating resorting to arbitration, and issued a 'final direction' that the contract should be fulfilled 'promptly and expeditiously'. The contractor wanted the department to take responsibility for the powerhouse work, thereby in Furkert's view altering the contract. He held that the design and construction of the powerhouse at the price fixed was the responsibility of the contractor. Meanwhile, by December 1927 the contractor had finished concreting the dam and had made good progress on the headworks and penstock intakes.



Above: The arched concrete gravity dam in the Arapuni Gorge nears completion. Note the entrance to the diversion tunnel at bottom right.

Below: A view of the Arapuni switchyard (top) and the powerhouse site (bottom), with the swing bridge providing access in the foreground. It was at about this time (1927) that the Public Works Department took over powerhouse construction after the English contractor declared the foundation conditions impossible because of water entering the site.

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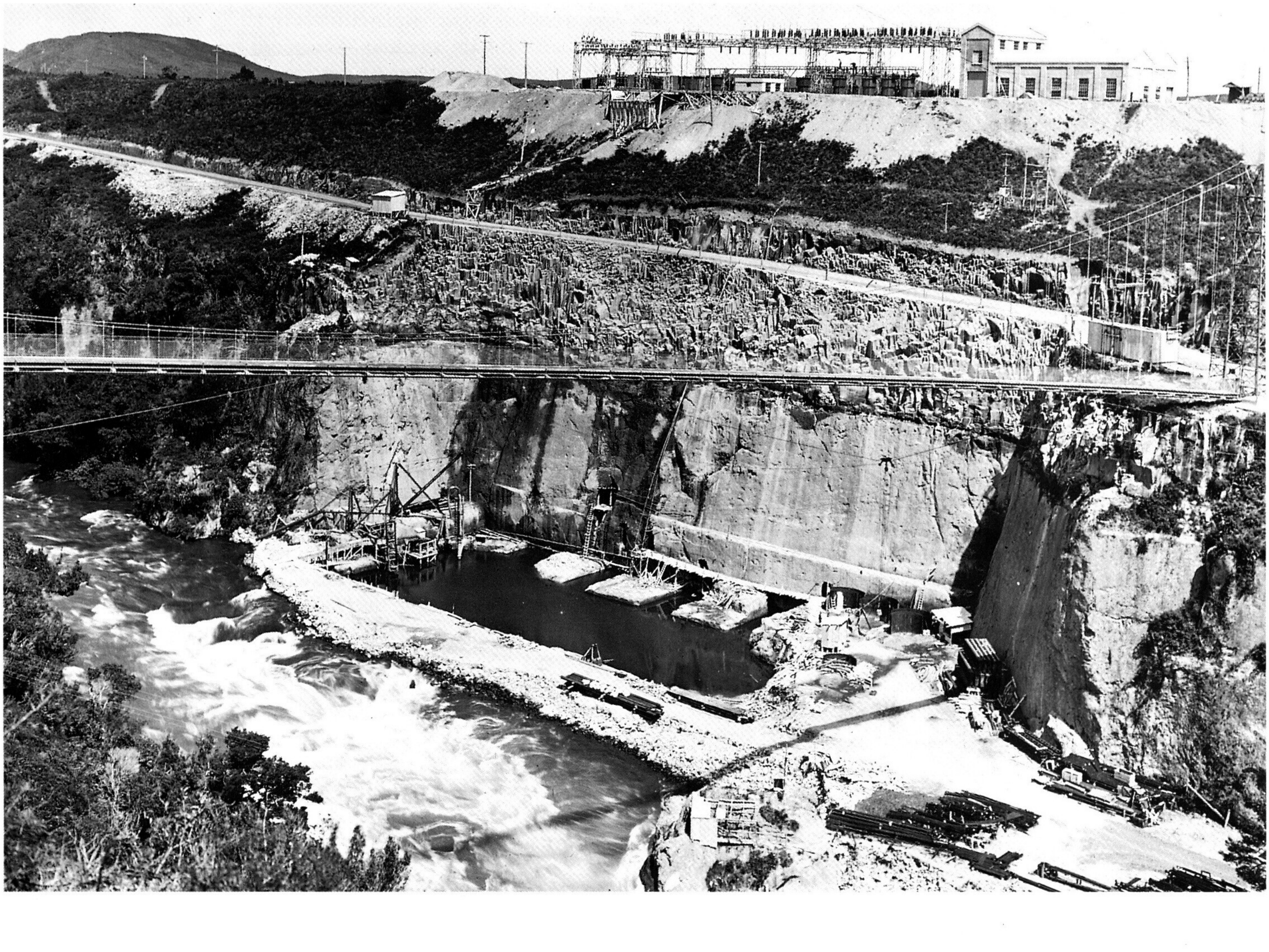


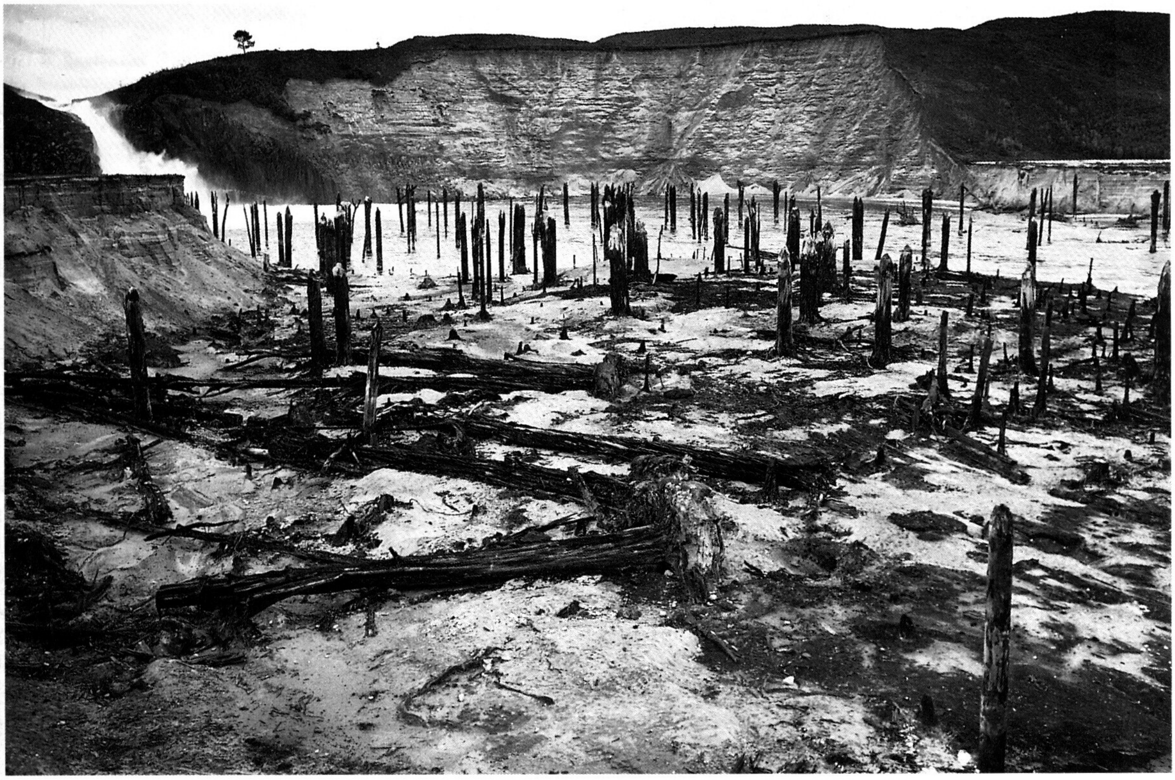
In August 1927 the Rt Hon. Edward Shortt, KC, PC, sailed for New Zealand on behalf of Armstrong Whitworth to attempt to persuade the government to accept a new plan for a relocated and remote-controlled powerhouse, for which the government would take responsibility. The government would also pay for any difference in cost between the two plans, and compensate the contractor for losses it had already suffered. On legal advice, and in view of Kissel's opinion that this offer would cost more and have no advantages in construction, the government declined the proposal. Shortt then tried to influence public opinion, but the department remained adamant that the powerhouse could be built quite easily and that the contractor was simply unwilling to try.

In December 1927 an agreement was reached whereby Armstrong Whitworth would fulfil its remaining obligations under the first contract and be paid at 'schedule rates' for what had already been done on the second. The Public Works Department would take over construction plant and materials at valuation. Furkert maintained that the real reason for the contractor's attitude was its loss of money on the easier part of the contract, which would have been compounded by the more difficult powerhouse job.

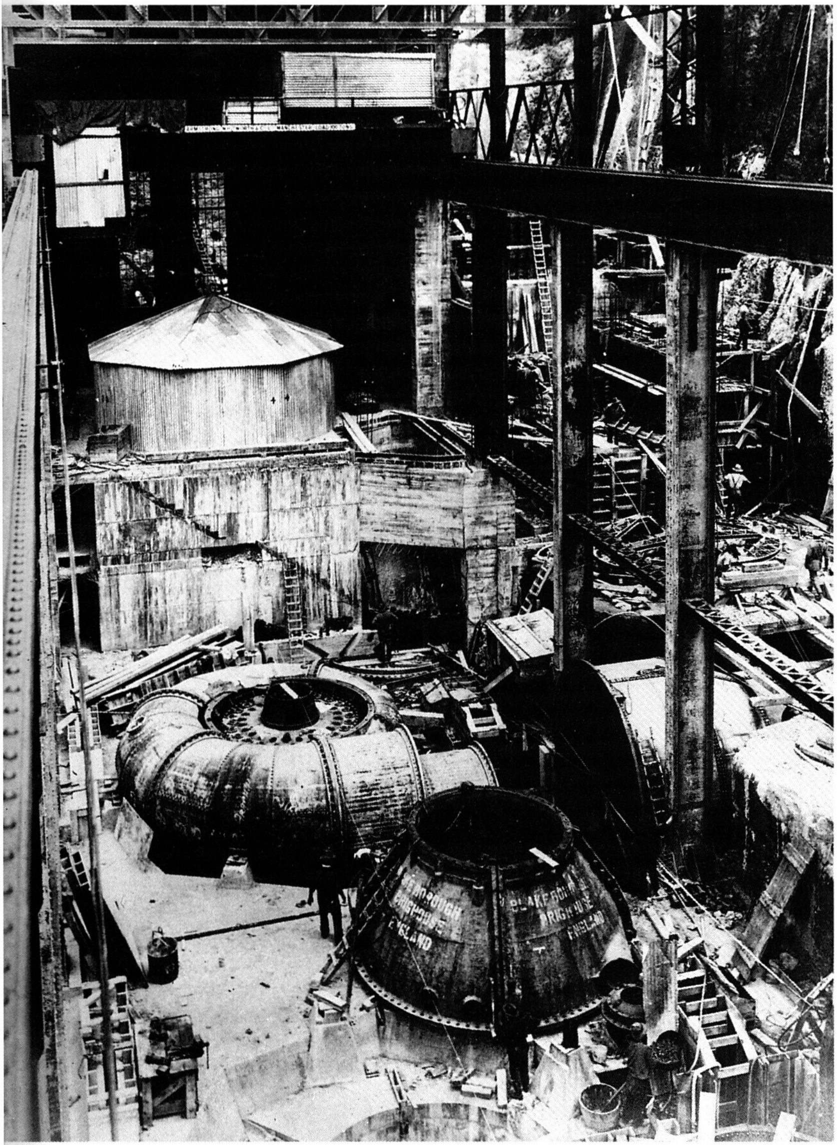
Once the hydraulic diversion-tunnel gates were closed (in early December 1927) and the lake filled (by 1 January 1928), the river was directed into its ancient course without much forethought. The headrace had been prepared, but not much attention had been paid to the spillway or the channel beyond, on the assumption that nearly all the water would go to the powerhouse. However, the delay in completing the powerhouse meant that all the water of the Waikato River went over the spillway and down the old channel. Not far below the spillway the channel dropped 120 feet down a 45-degree slope to the Waiteti Flat, an alluvial deposit some 40 feet deep. The result was that the falls were eroded and a deep channel was gouged through the flat, which uncovered an extraordinary preserved prehistoric forest of standing tree trunks.

What was worse was that the river rejoined its

When the diversion gates at Arapuni were closed and the Waikato River was directed into its old elevated course, the spillway section of the old riverbed was rapidly eroded away, exposing this preserved prehistoric forest of tree trunks on the Waiteti Flat and cutting back into the river terrace. This can be seen in this view, which shows the river plunging down the rapidly eroding slope behind the tree trunks.
Hall-Raine collection, Alexander Turnbull Library



bed some hundreds of yards further upstream than had been anticipated, which resulted in a much higher than expected water level at the powerhouse site. In less than a week about seven million cubic yards of sand and silt was carried into the main river, where it formed a sand bar, caused great problems downstream at Horahora, where the sand abraded the turbines, and compounded the water-level problem. An even greater concern was that the crest of the falls collapsed at least twice and re-formed closer to the spillway. In March 1928, 100 feet broke away; in August 1929 another 200 feet collapsed.



The interior of the Arapuni powerhouse, showing the end of a penstock entering the powerhouse and construction of the spiral casing for the No. 2 Francis turbine, in front of which is its valve housing. Behind is the No. 3 generator under temporary cover.

The department worked away at solving this problem. Meanwhile, it had taken over powerhouse construction at the end of January 1928. New foundations were designed. The job was made more difficult by a sand bar created by the contractor dumping excavated spoil into the river, which backed up the water. Huge pumps were installed, and in two weeks the leaking sandbag coffer dam was successfully plugged with cement grouting. By April 1928 construction of the powerhouse had finally begun. Cement was forced into the foundations at high pressure, and extra-heavy horizontal reinforcing created foundations capable of supporting far more than the required weight. The powerhouse was built rapidly, and completed in 1929.

The first machine began operating on 4 June 1929, before the powerhouse was completely finished, and Auckland at once received power on a trial basis. Horahora had been operating on overload since 1926. There was a good deal of nervousness, especially on the part of the Auckland Power Board, as to whether the additional work required could be done without interrupting generation. But Furkert was confident, promising in September 1929 a second machine within a fortnight and a third by Christmas. These machines duly appeared, but one had to be used as little as possible since it vibrated badly. Because it wanted the revenue, the department offered to supply the entire Auckland load. The Kings Wharf station was closed down in March 1930, and coal contracts were allowed to lapse. Within a few months, however, the power board was asked to generate from Kings Wharf again so that the Arapuni machine could be repaired.

Disaster struck on 7 June 1930. A crack appeared at the intakes, parallel to the river and along the line of the headrace. It extended 1,000 feet upstream from the powerhouse, and downstream to the falls. A whole block of country 2,000 feet long, 150 feet thick and 400 to 800 feet wide shifted slightly out and downwards towards the river gorge. A two-inch gap appeared in the concrete where the spillway joined the intake structure, and the penstocks broke away from the concrete encasing their tops, while the powerhouse itself tilted very slightly. Water found its way down the face of the powerhouse excavation and into the battery room. The suspension bridge across the river was shortened by more than an inch. It was essential to relieve the pressure and prevent further infiltration of water, so the station was closed and the headrace rapidly drained. The block that had moved then returned towards its original position.

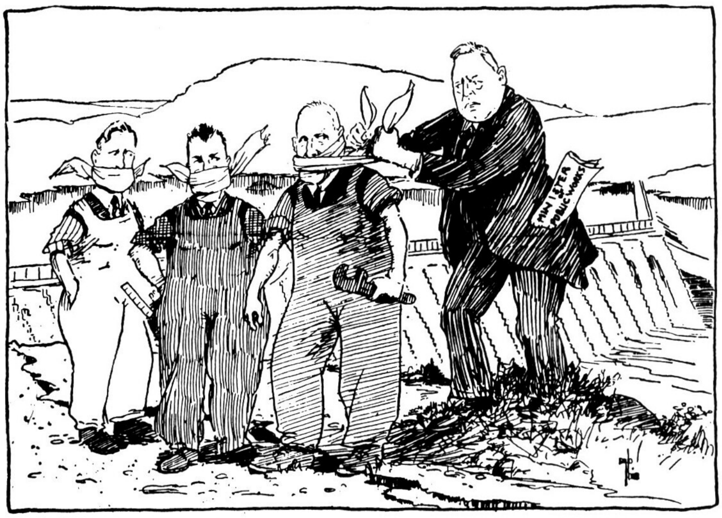
This serious problem provided fertile ground for criticism that the department was to blame for putting a dam and a powerhouse in an impossible site, and for not taking proper geological advice. Aucklanders were understandably angry. The power board, confident that it had unlimited resources of power, had just begun an extensive advertising campaign. There was no option in the short term but to reopen the Kings Wharf steam plant, juggle with Auckland's load, and install more steam capacity as quickly as possible. It was left to Kings Wharf, Horahora and other smaller plants, such as the Grand Junction steam plant, the Penrose diesel plant and the Okere Falls hydro-electric plant near Rotorua, to keep the north supplied.[20]

Auckland MPs extracted a number of financial concessions from the government, and a large 15 MW steam set was rapidly ordered for Kings Wharf and commissioned by early 1931. Meanwhile engineers and Ministers kept asserting that the dam was safe and that the erosion of the falls would lessen as more water was used for generation, while Opposition politicians went on the attack. Arapuni, said Bob Semple, was the 'greatest engineering blunder and political crime of its kind in modern history'. The government, on Furkert's suggestion, appointed an eminent Swedish consultant, Professor P. G. Hörnell, to report on the problem, as well as to assess Waitaki and Waikaremoana. He was in New Zealand for about two months.[21]

Hörnell attributed the problem largely to capillary action resulting from water in the headrace penetrating, swelling and fracturing the rock. While Furkert favoured replacing the headrace with a concrete flume that would not need lateral support, Hörnell suggested a complex, flexible lining of the headrace itself.

Hörnell had no doubts about either the suitability of the Arapuni site or the engineering competence that had gone into it. He considered the locality very suitable for economical power generation; and the design had made the best possible use of the site's topography. The dam was in the correct position, and its stability under full head 'complies with the main rules now universally conceded as governing the design and construction of a solid gravity dam'.[22]

In considering whether the opening of the crack could have been foreseen, Hörnell chose his language carefully. He stressed the uncertainties inherent in any large-scale hydraulic works, especially where unusual geology was involved, and also the normal obligation of the designer to achieve a 'reasonable prospect of safety' at the smallest possible cost. There would probably not have been a rupture if the bottom and sides of the headrace had been lined and watertight. The decision of engineers not to do this was, 'in the light of information known prior to the failure', a justifiable risk.



HUSH-HUSH AT ARAPUNI

In June 1930 the engineers became aware of a serious problem when a long crack suddenly appeared parallel to the river as a huge block of land shifted slightly out and downwards towards the gorge. This led to a considerable controversy, as the geology of the area had always been questioned. As the Auckland public waited impatiently for a diagnosis of the problem, cartoons like this one appeared.
Trevor Lloyd, *NZ Herald*, 21 June 1930

Repair work began in January 1931 along the lines suggested by Hörnell. This involved lining the forebay and part of the headrace, strengthening and sealing the line of the headrace crack with steel rods and grouting, and concreting the falls. The entire length of the overflow channel was also lined with concrete. The lining of the headrace and forebay used a combination of steel plates, concrete hexagonal slabs, and copious amounts of bitumen. Up to 800 men were employed on the repair work, and the cost was substantial.

It was some time before Arapuni was generating electricity reliably. The lake was refilled in

March 1932 and the station restarted on 3 April, but after several months and some heavy rainstorms the drainage system under the headrace failed. Some erosion occurred and the 'Hörnell lining' sagged into the resulting hole.

The station was designed for eight units. Three had been operating before June 1930, and the fourth and final unit in the initial installation was ready by May 1932. In 1933 approval was given for two more. This involved building major extensions to the powerhouse; work started in 1934 and both machines were in operation by February 1938. Two more machines, ordered in 1939, were not installed until 1945 and 1946 because of the war. The last four machines had a capacity of 21.6 MW each, while the first four were uprated to 17.85 MW. At this time Arapuni was absolutely crucial to the North Island, supplying half or more of its energy needs. The Arapuni settlement became a large permanent village, with 100 houses, a school, a post office, two churches, a cinema and a general store.

Over time there were to be a number of problems caused by the underdrainage system, which Hörnell had advised installing to ensure that the ground below the headrace did not dry out. Every failure was followed by further attempts to defeat the water, mainly by extensive grouting through the lining. After a large section of the lining collapsed in 1958, it was decided to close off the underdrainage system. No further problems were encountered.

More recently, attention has been given to the rather too low 'design flood' capacity of the headrace and spillway. At the time of construction the flows reached by past major floods were unknown, and the spillways at both Arapuni and Karapiro are, by modern standards, underdesigned. These concerns were compounded by the later development of a chain of stations and headponds down the entire Waikato from Taupo to Arapuni. This deficiency was largely overcome by detailed operating rules for passing floodwater down the river through the various power stations and associated spillways. A major upgrading of the spillway and the relining of the headrace have just been completed.

Arapuni stands testimony to the ability of early engineers to design and construct a large scheme on a complex site with little prior experience and much more meagre resources than were available to their successors.

Opposite above: Following the appearance of the crack, an eminent Swedish engineering consultant, Professor P. G. Hörnell, was engaged to report on the problem and recommend solutions. He suggested a watertight lining of the headrace to prevent water penetrating the rock, and a lining using steel plates, bitumen and hexagonal concrete slabs was devised and laid down. It is shown here in early 1932.
Evening Post collection, Alexander Turnbull Library

Opposite below: An aerial view of the completed Arapuni scheme *c.* 1937, showing the Arapuni village at left, Lake Arapuni and the dam in the middle distance, the powerhouse in the gorge and the headrace at centre, and to the right the spillway and concreted falls down to the Waiteti Flat. At this time the powerhouse was being extended to accommodate further units.
Gordon Burt collection, Alexander Turnbull Library

Waikaremoana

Waikaremoana was seen as an attractive proposition from the time of the first surveys.[23] The area has a high rainfall, and the potential total head was close to 1,500 feet. The lake, at an altitude of 2,015 feet, offered massive storage capacity, and its average flow from the outlet was almost as much as the Waikato River. It was formed some 2,000 years ago by a gigantic landslide that blocked the original Waikaretaheke River. Except after prolonged wet weather, when it overflowed, the lake had no surface outlet, but large quantities of water leaked out through the natural dam, and much of this eventually came together to form the Waikaretaheke River. Birks had recommended that the water be diverted into a small lake at Kaitawa and then dropped more than 600 feet to a powerhouse at Tuai on the Whakamarino Flat. From Whakamarino a further head of more than 350 feet was available, which was utilised for the Piripaua scheme. If a way could be found to get at the lake water directly, the balance of the head (nearly 450 feet) above Kaitawa could also be exploited.

There had long been local agitation for development. In 1907 the Napier Chamber of Commerce had urged the government to commit funds to the project. In 1910 Wairoa sought permission to build a scheme that would later dovetail into a larger government one, but the government refused to allow the town to go beyond using water to produce power for lighting, and warned that all prospect of a government scheme could be lost if the east coast towns put in their own small hydro-electric works. Hastings, Napier and Wairoa all had steam plants that were hopelessly overstretched by the end of the First World War,

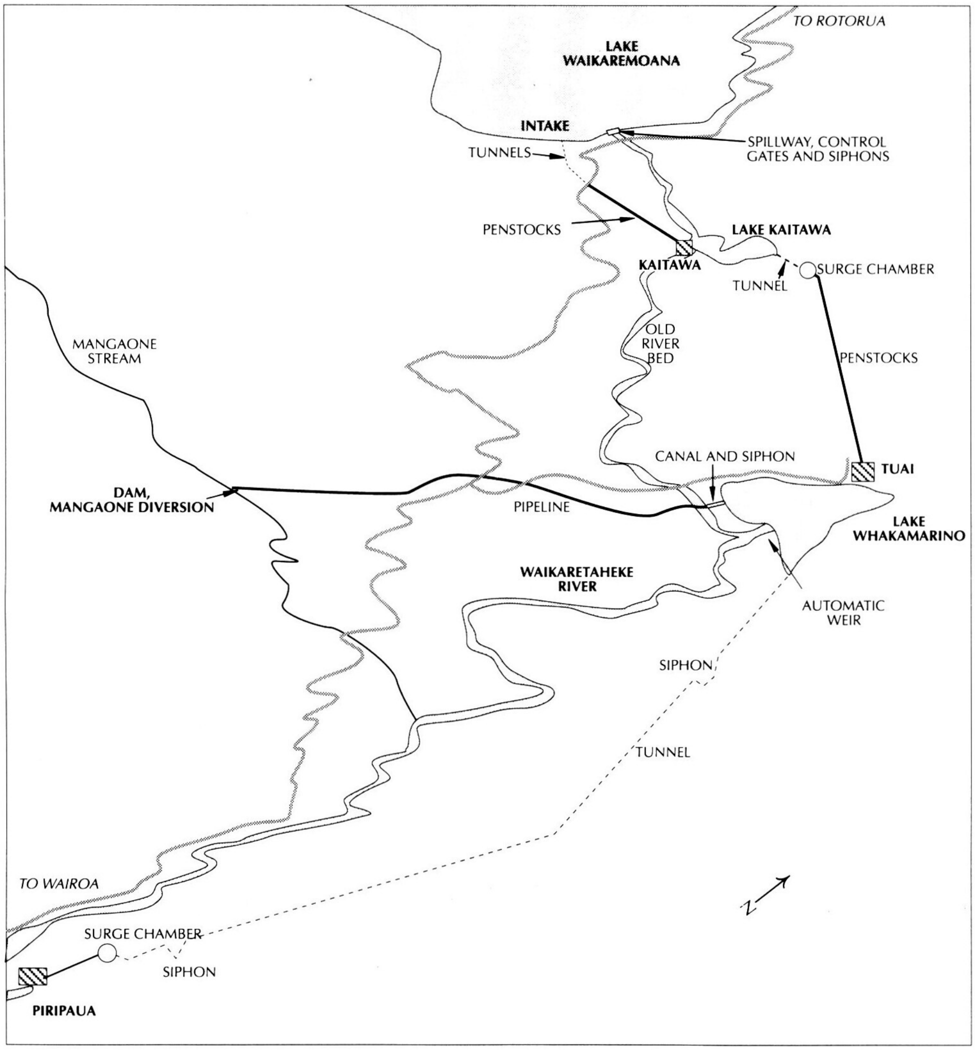
Waikaremoana

The overall scheme comprises three linked power stations, with a total capacity of 124 MW, which are centrally controlled from Tuai.

Tuai station: Constructed 1926–29. Head 676 feet. Water from Lake Kaitawa is taken through a 500-foot-long canal and 792-foot-long tunnel into a surge chamber and three penstocks, 3,580 feet in length. Three horizontal Francis turbines drive generators, two of 16 MW installed in 1929 and the third of 20 MW added in 1939. Total capacity is 52 MW.

Piripaua station: Constructed 1939–43. Head 370 feet. The water discharged from the Tuai station forms Lake Whakamarino, a reservoir for Piripaua, from which a tunnel, 16 feet in diameter and 9,400 feet long, leads to a surge chamber and two penstocks into a powerhouse containing two turbines driving 20 MW generators. Water is discharged into the Waikaretaheke River. Total capacity is 40 MW.

Kaitawa station: Constructed 1943–48. Head 433 feet. Water is taken from Waikaremoana through the natural barrier near the old outlet by a forebay and tunnel. The tunnel bifurcates and delivers the water to two penstocks and two turbines and 16 MW generators in the powerhouse. Total capacity is 32 MW.


TO ROTORUA
LAKE WAIKAREMOANA
INTAKE
TUNNELS
SPILLWAY, CONTROL GATES AND SIPHONS
PENSTOCKS
LAKE KAITAWA
KAITAWA
TUNNEL
SURGE CHAMBER
MANGAONE STREAM
OLD RIVER BED
PENSTOCKS
CANAL AND SIPHON
TUAI
DAM, MANGAONE DIVERSION
PIPELINE
LAKE WHAKAMARINO
WAIKARETAHEKE RIVER
AUTOMATIC WEIR
SIPHON
TUNNEL
N
TO WAIROA
SURGE CHAMBER
SIPHON
PIRIPAUA

and also had great difficulty in obtaining coal supplies. This was a particular problem for Wairoa because of the bar at the mouth of the river. Gisborne had no electricity supply at all, and was investigating obtaining it from a private company that wished to develop a hydro-electric scheme.

In spite of agitation by local bodies, it was clear that any development at Waikaremoana was a long way off. It could not be justified economically in terms of the electricity demand of the east coast and the Bay of Plenty, and would have to wait until Mangahao was fully loaded and more power was needed in the south. Nevertheless, a Waikaremoana Hydro Electric League was formed in 1917 following a conference of local authorities between Dannevirke and Gisborne. In March 1918, a party of MPs went on a tour of Waikaremoana hosted by the league. An exasperated Parry told the league he greatly wished that people would forget about the sources of power and concentrate on the adoption of a universal system of distribution. This was an invitation to form power boards, but it was to be years before Hawke's Bay could agree to form one. The chief sticking-point was the refusal of Napier to face the expense involved, especially as no-one could say when power would be available. Even so, surveys were undertaken that year.

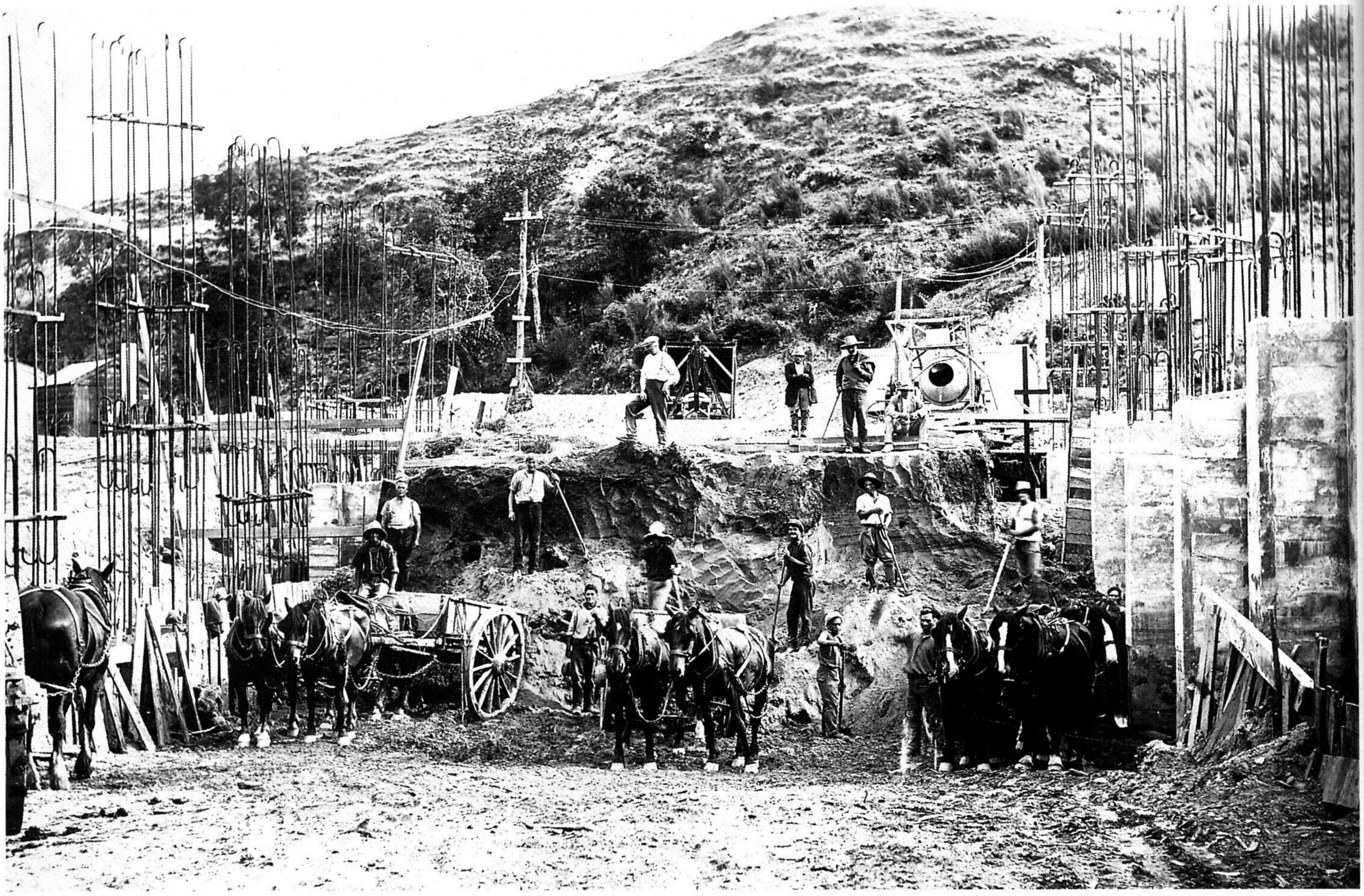
Early in 1919 the Minister of Public Works, W. Fraser, suggested that the local authorities might make a start on the project and the government take over later. Wairoa Borough and County responded quickly and conceived a scheme that won Birks' support. The Wairoa Power Board, formed in July 1920, raised a loan to transmit electricity 23 miles to the town from a small plant on the Whakamarino Flat which could later become part of a larger scheme. This would comprise two Pelton wheels driving 350 kW generators. The government was willing to acquire the land needed for the headworks, buy the Pelton wheels and generators, and lease the project to Wairoa for up to five years. Later that year Massey, with an election in the offing, had Cabinet approve a start on Waikaremoana 'as soon as practicable'. This meant, in effect, the Wairoa project, which was opened in 1923. Later, another Pelton-driven 1,000 kW generator from Waipori was added to the plant.

Anderson had as early as 1916 started serious investigations, which continued into 1918. Surveys, roading and a tentative development plan had been completed by 1922. However, Hawke's Bay local bodies continued to be difficult. Their estimates of likely demand were too low, and Coates considered that Waikaremoana should be delayed. Substantial increases in estimated costs also played an important role in this decision. There was an outburst of fury in 1924 when Hawke's Bay was offered power from Mangahao, which was about to open. (A transmission line connecting Napier with the Mangahao system would be essential if North Island hydro-electric developments were to be linked.) Napier and Hastings believed that the government was trying to foist expensive power on them rather than developing the cheapest and best source. They insisted that they could do better by expanding their own steam plant.

In 1924 a Hawke's Bay Power Board was finally formed, but wrangling with the boroughs continued. Not until 1926, and then only after an ultimatum that they would miss out, did they agree to take the power that would shortly be available. Their agreement gave Kissel the conditions he wanted. He had firm guarantees that within five years all that Mangahao could produce would be paid for, and he was sure that the station would in fact be fully loaded in about two years. Cabinet authorised the Tuai scheme that year.

Preliminary work, such as the erection of camps at Whakamarino and Kaitawa and the surveying of transmission lines, had been undertaken during 1925–26. Construction, which began in 1926, was largely by pick and shovel, although a power shovel was used for the surge-chamber excavation and horse-drawn scoops were employed on the penstock slopes. Work on the diversion of the Waikaretaheke River began in July 1926. The river was temporarily diverted in October 1927 to allow construction of the weir that would divert the river by a race into Lake Kaitawa. The lake was raised ten feet by an earth dam. From there a canal and tunnel led to a surge chamber, from which two penstocks ran down to the powerhouse. Heavy equipment had to be broken down and transported on the massive wooden trailer towed by a steam traction engine that had originally been used at Coleridge.

The project went well, with the penstocks being finished in October 1928, the tunnel filled with water in November, and the first unit installed in the completed powerhouse by the end of the year. Because Mangahao was overloaded, the first unit was commissioned quickly in February 1929 and the second unit followed in mid-year. Control equipment, advanced for its time,

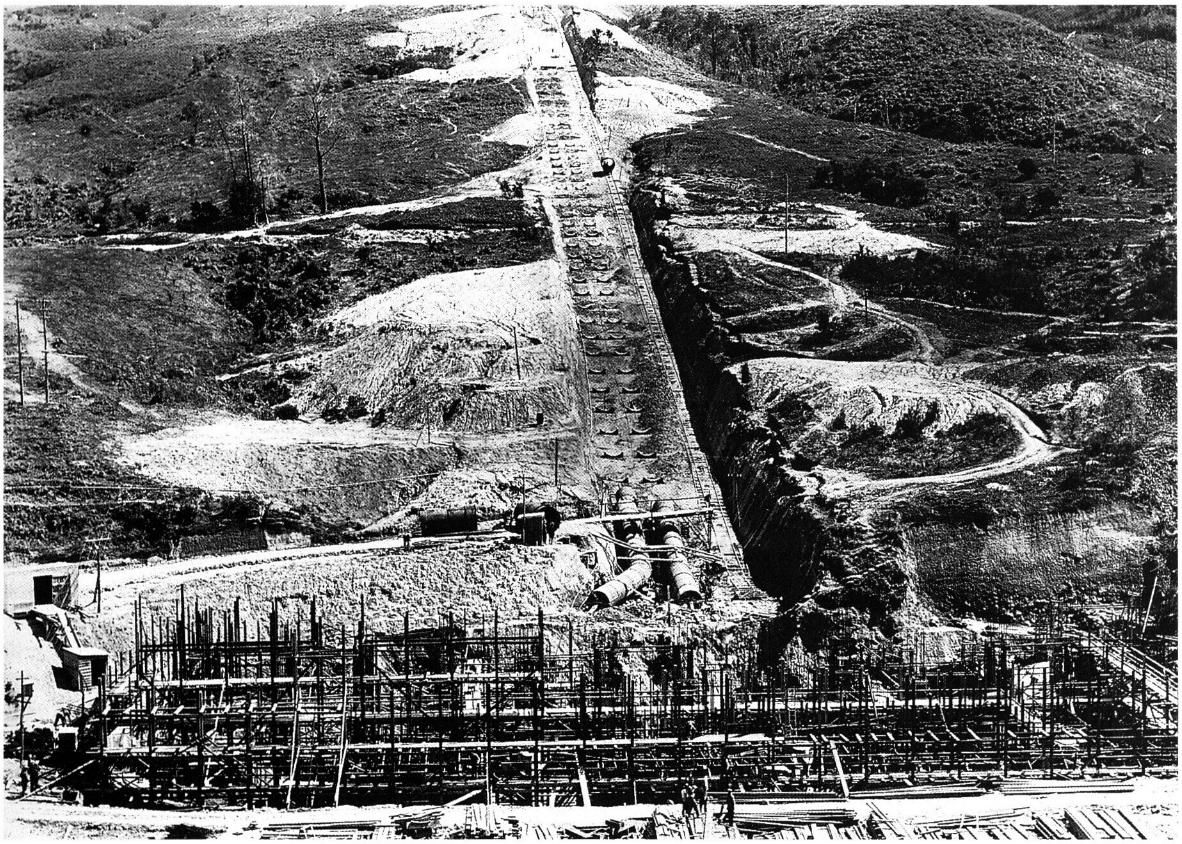


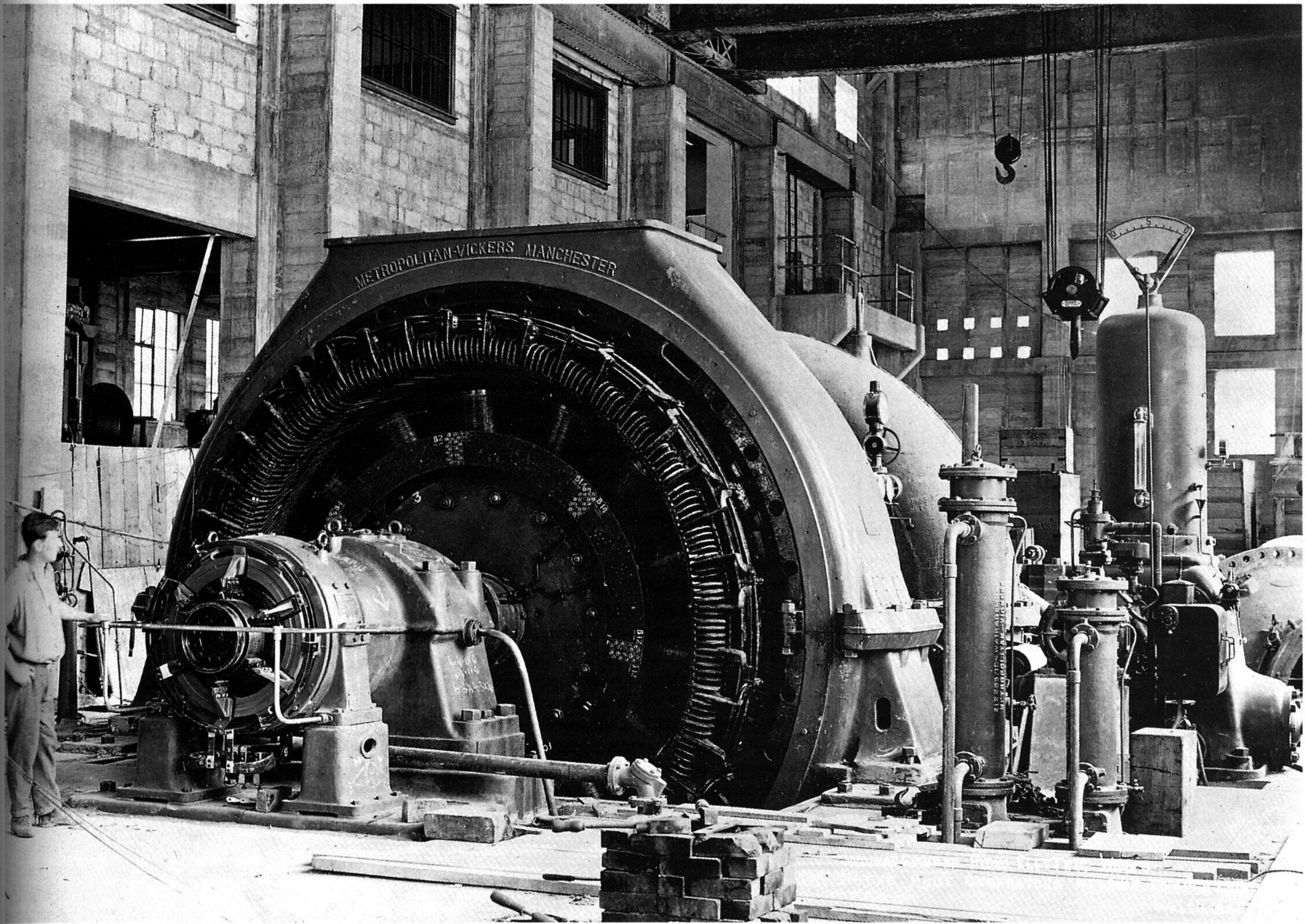
Above: Labourers, mostly Maori, make a start in April 1927 on the centre part of the foundations for the Tuai powerhouse, using horse-drawn carts to shift spoil.

Left: Much of the Tuai construction work was done with pick and shovel. Here a Maori gang excavate the anchor block for the north pipeline in April 1927.

Opposite above: Rapid progress was made on the Tuai powerhouse during 1927. By the end of September timber-work for concreting had been erected, the penstock slopes prepared and supports and the first sections of the penstocks laid.

Opposite below: Installation of the horizontal Francis turbines and generators in the Tuai powerhouse nears completion.




METROPOLITAN-VICKERS MANCHESTER

was installed in the powerhouse, and the scheme was officially opened on 20 November 1929. In that year Tuai was linked to the Mangahao system via a 60-mile dual line to Napier. This was the first interconnection of stations, and much of the lower half of the North Island now became integrated into a single transmission network. A more balanced system utilising different kinds of plant now became a possibility if the storage capacity of Waikaremoana could be tapped. While Mangahao and Arapuni had little seasonal storage, Waikaremoana had, at least potentially, storage sufficient for the entire linked system. Provision was made for a third unit, to be installed when additional water was available, and this, together with a third penstock, was added in 1939.

By the 1930s all the North Island power plants were linked into a single transmission system. Mangahao was connected to Wellington in 1924, to Napier in 1927 and with Waikaremoana in 1929. By 1931 New Plymouth and Mangahao were connected, and in 1934 the Stratford–Arapuni line joined together the two halves of the North Island system. Parry's vision of an interconnected system had been realised.

But a basic problem, which left the North Island system at the mercy of prolonged dry seasons, remained: there was virtually no storage capacity. In the early years of Mangahao's operations minimal storage was available, and it was soon unable to meet the demand. The construction of a second dam on the Mangahao River, the opening of the station at Tuai, and linkage with Mangahao relieved the pressure for a time. Tuai was used as a base-load station, which allowed Mangahao to hold back its limited storage for times of peak demand.

Attention was now turned towards making use of the huge storage capacity of Waikaremoana. The slip at its outlet had provided a natural earth dam some 800 feet high. It was argued that the level of the lake should be controlled and the leaks stopped, in order to take full advantage of these natural assets. In the 1920s there was much discussion and investigation of how to do this.

One proposal was to drain the lake to the (unknown) level of the lowest leak, by deepening a channel where the lake overflowed, constructing a diversion tunnel, or using a series of massive siphons to take the water over the top of the slip. The leaks could then be sealed with concrete. Another possibility was to build a coffer dam to separate the affected face from the rest of the lake. A further possibility — the simplest and cheapest, though not necessarily the safest — was to tap the lake by tunnelling into it below normal water level. The lake could then be lowered and the leaks revealed stopped. This idea had the additional advantage that it would result in a substantial range for storage.

In 1931 Furkert wrote to the Minister about the environmental issues raised by this proposal. If the lake level was permanently lowered and then fluctuated over a range, most of its existing charm would be lost, since this depended on the shores being bush-covered to the water's edge. A varying width of bare rock and unsightly mudflats would be exposed. Furkert himself was not particularly concerned about this, arguing that in such a wet climate nature would soon ameliorate the damage, but he was aware of the potential for serious public criticism.

After Tuai was completed, a small team began exploring caves at the lake outlet, with divers mapping leaks from the lake bed. After a great deal of investigative work, Furkert was confident by September 1931 that most of the leaks were within 30 to 50 feet of the normal lake level. However, Hörnell, who inspected Waikaremoana as well as Arapuni, thought that the slip could be unstable owing to invisible internal erosion caused by the amount of water flowing through it. His views did not impress New Zealand geologists and engineers who considered that, while the barrier would undoubtedly change over the span of geological time, it was on a human timescale permanent and stable. Confidence in this view had been strengthened when the natural barrier showed no sign of being affected by the very severe earthquake of February 1931. However, the onset of the Depression and a consequent slackening of demand for electricity brought a halt to investigations.

Initial work on the Kaitawa powerhouse site was carried out in the early 1930s, but this was stopped because the earth dam was insufficiently consolidated. By now the supply situation in the southern North Island was becoming particularly acute. From 1934 power from Mangahao and Tuai was supplemented by means of the transmission line from Arapuni to Stratford. Kissel argued that the high head made storage at Waikaremoana particularly valuable, since less water would be needed to produce a unit of power. The efficiency of the entire system would be enhanced if Arapuni was used as much as possible and water was stored in the other lakes against peak demand.

The practical result of Hörnell's concern was to reinforce the idea of tunnelling into the lake.

Work recommenced in 1934–35. A test shaft was put down 50 feet below water level and preliminary drives were made along the line of the proposed tunnel, but the work was stopped in peremptory fashion in January 1936 by Bob Semple, the new Minister of Public Works, who had been a miner and tunneller. After inspecting the site in December 1935, Semple considered that the work was very hazardous.

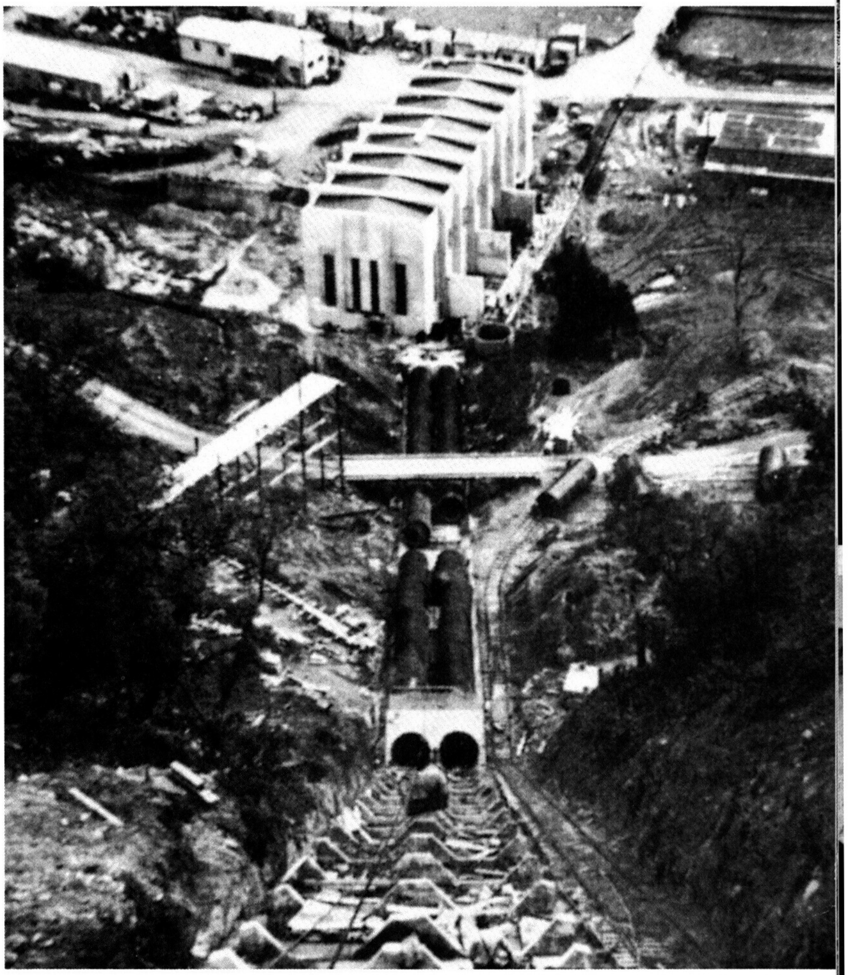
These difficulties led to a start being made instead on the lower scheme of Piripaua. This project involved an earth dam to form Lake Whakamarino, a canal and tunnel, a surge chamber, penstocks, a new channel for the Waikaretaheke River and a bridge over the canal so that the powerhouse could be built in the old riverbed. Construction work began in 1939 but was to be subject to many delays during the war. Two camps were set up, with 100 married and another 100 single men's huts and a YMCA building. In line with Semple's mechanisation policy, three large tractor/bulldozers and two diesel shovels were used for excavations, and diesel locomotives carried spoil out of the tunnel drives.

By 1940 the numbers employed had risen to more than 350. Excavation of the canal and powerhouse foundations had been completed, and the excavation of the surge chamber, foundation works for the dam and the driving of the tunnel were being undertaken. The Piripaua bypass had been completed and the river diverted. The canal was finished and the tunnel largely driven during 1941, and the dam, penstocks and powerhouse were completed in 1942. The first unit was commissioned in 1943, and the other the following year. In order to increase the flow into Lake Whakamarino, water was diverted into it from the Mangaone and Waikaretaheke Rivers in the period 1946–48.

Work on Kaitawa recommenced in 1943, with Semple now expressing confidence in the safety of the tunnelling. This project involved a forebay on the shore of Lake Waikaremoana, and a tunnel, which bifurcated at the headgates, through the massive slip at the lake outlet. Water was taken from the two tunnels to the powerhouse via penstocks and thence discharged into Lake Kaitawa.

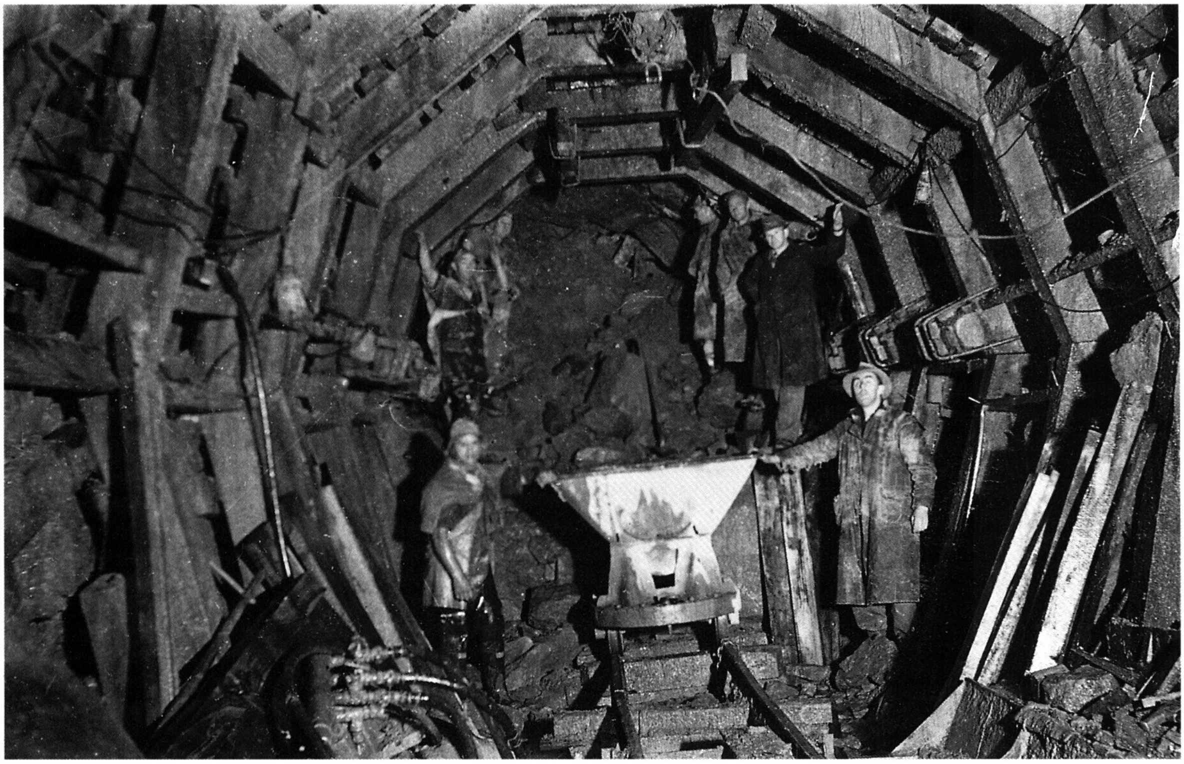
The tunnelling through the broken rock of the slip took nearly four years from December 1943 to complete, in conditions which have been described as the most difficult in New Zealand. Extensive grouting was required around the intake and above the line of the tunnels. By early 1946 the powerhouse was almost finished, and a year later the tunnels had been driven.

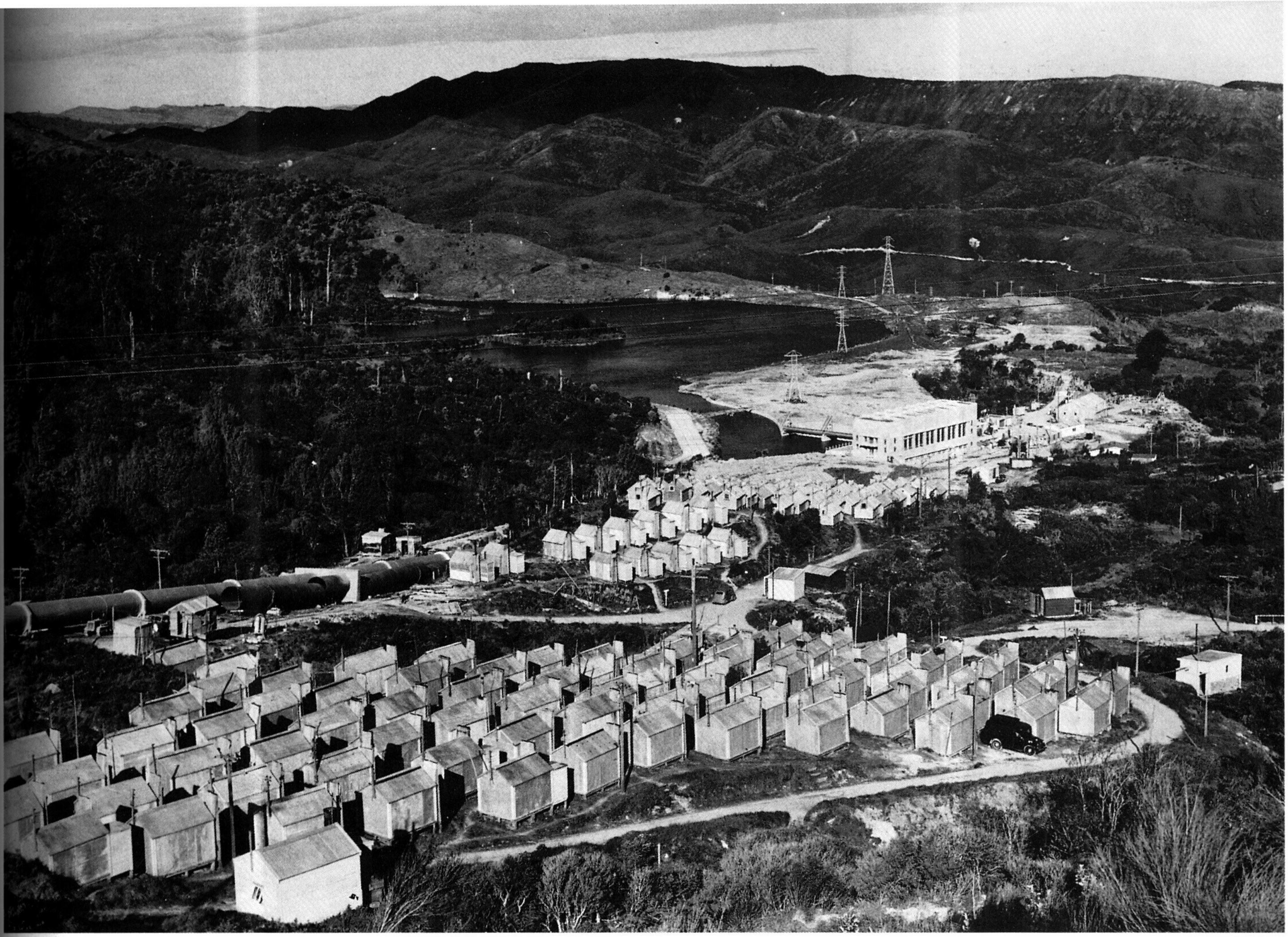
Rock and rubble had still to be removed from the intake by blasting to allow water to enter — a tricky job. Under pressure of time, this task was carried out with increasing boldness at the direction of N. R. Carter, the Resident Engineer. In the end Carter detonated a single huge blast comprising almost two and a half tons of dynamite.



Looking down the line of the two penstocks towards the virtually completed Piripaua powerhouse and the new Waikaretaheke River channel, October 1941. The powerhouse was built in the old riverbed.

Photograph courtesy of Mr G. G. Natusch.





Above: A view of the Kaitawa powerhouse and public works camp, with penstocks in the process of construction at left. Lake Kaitawa can be seen in the middle distance.

Opposite above: The Kaitawa tunnel through the slip at the outlet to Waikaremoana in October 1946, just as it was holed through into the intake chamber. The extreme difficulty of the job is shown by the broken rock and extensive shoring.

Opposite below: Construction of the intake for the Kaitawa scheme, October 1947. This involved a large stepped concrete chamber, at the bottom of which a tunnel takes water to two pipelines. The intake channel has yet to be excavated towards the lake.

This explosion did the trick, albeit at the cost of some damage to the concrete of the intake, but earned 'One Shot' Carter an official reprimand from head office for his failure to consult higher authority. The tunnels were completed in early 1948, and the first generating unit was commissioned in April, and the second in October.

In 1945 three temporary siphons four feet in diameter were installed to allow the drawing off of up to 840 cusecs for the lower Waikaremoana stations when it was necessary to build up storage in Taupo. In the autumn months of 1947 and 1948 the lake was reduced to unsightly historic low levels to meet the need for power, but this did greatly assist the completion of the intake for Kaitawa. In the mid-1950s permanent siphons were installed for both flood control and the delivery of water to the lower stations via the old riverbed if Kaitawa was out of commission. When Tuai was shut down, water could be released from the Kaitawa station into the Waikaretaheke for diversion into Lake Whakamarino and so to Piripaua. Thus each plant could be run independently if necessary. Work on sealing leaks at the outlet from Waikaremoana was to continue until 1955.

This marked the completion of the plans for the North Island which Parry had articulated in 1918. The Mangahao, Arapuni and Waikaremoana schemes laid the foundations for an integrated network of hydro-electric power stations which, by the time Kaitawa was finished, was being greatly augmented by the comprehensive development of the Waikato River (described in Chapter Seven).

CHAPTER FIVE

The South Island

PARRY'S PLANS had focused on the North Island. In the South Island the well-established stations of Waipori, Coleridge and Monowai were coming under increasing strain from the mid-1920s.

By 1923 Coleridge was supplying Christchurch, Ashburton and Timaru, and Oamaru was soon to be reached also. Coleridge's limits and the growth of demand in Christchurch were the key considerations. In 1925, as growth slowed, Kissel thought that Coleridge would suffice for another six years. However, Christchurch city did not have the same confidence and threatened to consider a project of its own on the Waimakariri River. There had already been power restrictions, and times when Coleridge could cope only by producing up to 30 per cent more than its rated output.

Kissel argued strongly that local development should not be allowed. He reasoned that it was now accepted that electrical development, whether state or private, should be undertaken on a large scale and by authorities controlling sizeable areas. The government consequently made it clear that it would not authorise Christchurch to borrow £1 million to spend on the proposed Waimakariri River scheme.

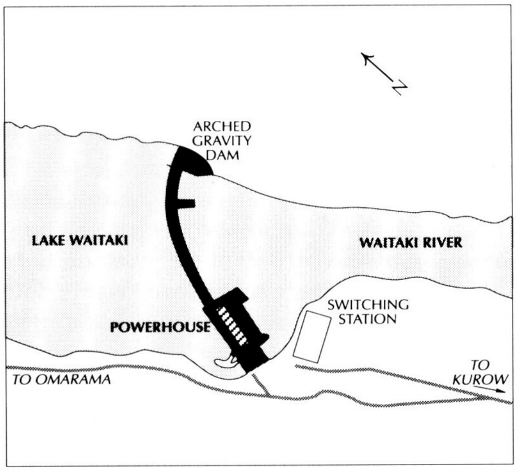
Serious South Island investigations began in 1925, primarily because of the need to supply Canterbury but also to take account of future linkages that would permit supply to Central Otago. G.P. Anderson was in charge. His brief was to look at possible sources between the Waimakariri and the Waitaki, with the Clarence a possibility only if the needs of Christchurch outweighed everything else. Significantly, Kissel sent Anderson a specially bound copy of Hay's 1904 report. Although Anderson was instructed to keep a 'purely open mind' and not confine himself to schemes suggested previously, it seems clear that both Kissel and Anderson thought from the outset that the Waitaki River was a prime prospect.

Waitaki

Detailed proposals for two possible projects at Lake Tekapo had been drawn up some time before by an English consultant for the Tekapo League, which represented South Canterbury interests.[1] Because they were based on investigations carried out at the turn of the century, the proposed schemes were now considered too small, but it was also clear that any serious development on the upper river would have to be of a magnitude that would not be needed for many years. The valleys between the Mackenzie Country and Kurow therefore became the focus of attention.

The main investigations were done by E. W. McEnnis, who was much harried and scolded by Anderson because of growing political pressure to decide on a site. As early as December 1925 the Minister was told that there was a highly promising site immediately above Kurow, and that surveys of possible schemes on the Waitaki were nearly complete. Others praised McEnnis for his determination to do a thorough job. His survey levels, 'for the next 40 years, controlled power developments in the Waitaki Valley'.[2] Various difficulties slowed progress. Records could not be found of previous levelling on the river, and it was not easy to get river gauge readings taken regularly. When it became clear that McEnnis would have to drill to determine the depths of shingle in the riverbed, he had to make

Waitaki: Constructed 1928–34. Head 70 feet. A concrete gravity dam, 157 feet high and 1,778 feet long, contains an integral intake and a 1,200-foot-long ungated spillway over the crest of the dam. There were initially five penstocks leading to turbines driving 15 MW generators in the powerhouse on the right bank. Three turbines were of the Francis type and two of the propeller type. Increased storage of water upstream, following the building of the Tekapo and Pukaki control works, allowed the extension of the powerhouse and the addition of a further two penstocks, two Francis turbines and 15 MW generators in 1954. This raised the total capacity to 105 MW.



do with unsatisfactory pontoons that leaked and sank. McEnnis' car was not suitable for the rough terrain and was frequently out of action, so another had to be purchased.

There were many arguments in favour of the Waitaki. If the South Island system was to be interconnected, it was logical for the new supply to be close to the physical centre of the island. Any station on the Waimakariri or Rakaia Rivers would feed into the system at Hororata, where Coleridge power already entered it. A station on the Waitaki would be at a lower altitude than one on either of the other rivers, so that supply would be less in danger of interruption owing to weather conditions — snow had proved the greatest menace at Coleridge.

The possibilities for expansion on the Waitaki were also far greater than elsewhere. The river's mean flow was 12,400 cusecs (at the Waitaki power station site), its minimum flow was three times that of the Waimakariri, and there was much less difference between minimum and maximum flows. Lakes Tekapo, Pukaki and Ohau acted as natural controls and helped limit the shingle movement so evident in Canterbury rivers. These lakes could themselves become part of the system in the future. However, there was still a great difference between Waitaki's high and low flows, and the highest flows came not in winter, when demand was at its peak, but rather during the spring and summer thaw, particularly in spells of hot nor'wester winds. One problem was that the river was observed systematically only from 1925 and no major floods had been monitored.

Early in 1927 it was announced that the next South Island project would be on the Waitaki, though a definite site had not yet been decided upon. There was little opposition from Christchurch, but anxiety increased about the ability of Coleridge to supply the city. Nor was there much confidence that the Waitaki station could be built in three years as promised, or that investigations were proceeding fast enough. The Canterbury Progress League appointed a Vigilance Committee in February 1928 to hurry the government along. W. Downie Stewart had in 1927 asked the Public Works Department not to proceed with new work before fully consulting Treasury, and early in 1928 he stated that investigations only were planned for the current year. Meanwhile electricity consumption in Christchurch continued to increase. Virtually all supply authorities were anxious to sell more power in order to meet their revenue needs.

The department, which was looking for the widest stretch where there was a solid rock bottom not too far down, found it difficult to decide between a number of possible sites. The first site investigated was at Roseneath, nine miles above Kurow, near the junction of the Wharekuri Creek and the river. The Aviemore dam was to be built there many years later. This site had major advantages: more storage was available, and it would be comparatively easy subsequently to build a second dam further down the river. There was also an island that would help with the diversion of the river. But the fact that solid rock for foundations was more than 40 feet down proved decisive. A local contractor suggested that a site near the Awakino confluence had a rock bottom only fifteen to 25 feet down. It was confirmed that there was good rock at each abutment, and this appeared to extend across the full width of the valley. This site, only four miles from the railhead at Kurow, was chosen in 1928.

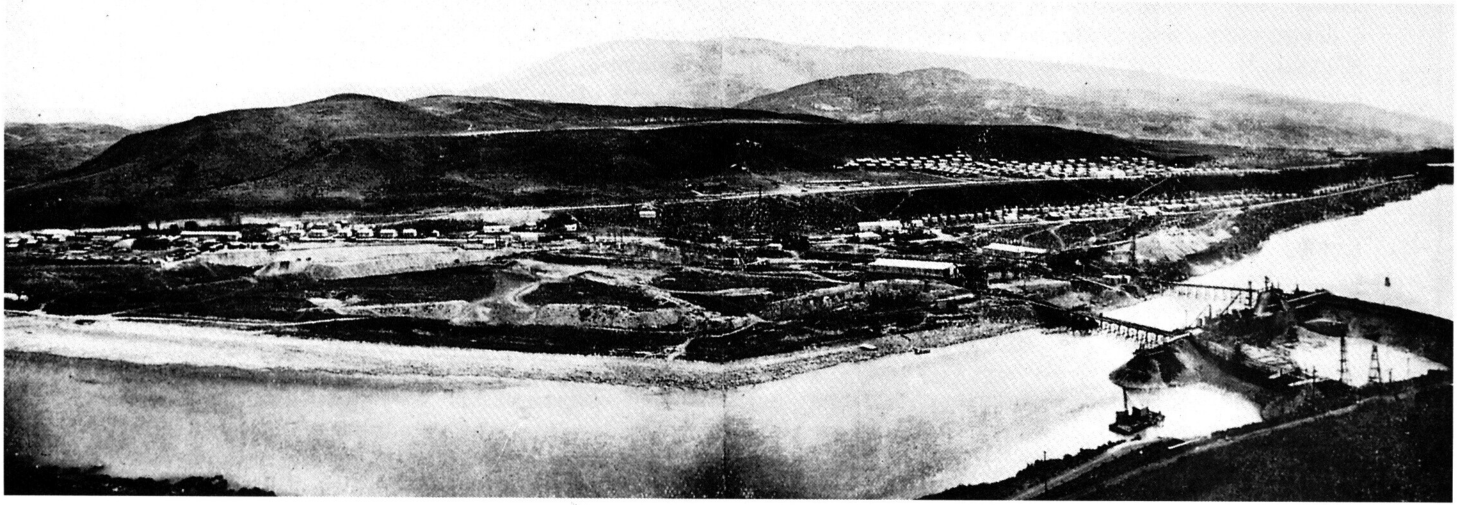
The cost of diverting the river through a tunnel was considered too high, and construction would have taken too long. For the first time in New Zealand it was decided to build a dam across a major river without a diversion. A coffer system was devised to build part of the dam in the undiverted river. Advantage would have to be taken of the winter periods of low water, but it was not intended to stop work in the flood season.

Construction began in mid-1928, with an optimistic completion date of 1931. By December 1928 the extension of the railway from Kurow, two trestle bridges across the river and workmen's accommodation had been completed. Work went on in three shifts 24 hours a day, with the men working under batteries of floodlights at night. Waitaki was to be the last major dam built by pick, shovel and wheelbarrow, manual methods being adopted deliberately to occupy the unemployed. More than 700,000 cubic yards of spoil had to be excavated, much of it loaded by hand into horse-drawn carts or trucks on rails, and 275,000 cubic yards of concrete was mixed and poured.

The site was isolated, windswept and extremely cold in winter. Waitaki Hydro was a public works camp unique in its time, partly because of the size of the project and the climate, both of which necessitated it being more of a town, but also because it largely kept to the pattern of improved living conditions that had emerged in the 1920s — most public works camps reverted back to tents during the Depression.[3]

Waitaki Hydro was constructed on two river terraces. The main upper camp had full facilities, while a second camp on the lower terrace, completely exposed to the wind and called 'Siberia', comprised more temporary accommodation, which was erected for the influx of relief workers in 1933. A third camp, 'Geddesville', was on the lower terrace downstream from the dam. There was also an unofficial shantytown on the fringe of the camp, at the 'Willows' beside the Awakino bridge. This was formed by men who were unsuccessful in obtaining work at the site and scraped together a living by casual work, rabbiting, and fossicking for gold.

The senior staff lived in concrete-block houses, which were later to be used for the permanent village. Single men lived in 10 × 8 feet huts with a small stove, bed and mattress, table and a stool, and married men had somewhat larger but still basic quarters. Some 350 houses and 700 huts were built. There were more than twenty shops, a post office, a YMCA recreation hall, three large cookhouses, bathhouses, a medical hut and a community hall. On the top terrace were a sports ground and a gymnasium. The recreation hall had a library, reading and writing room, billiard room and a canteen selling cigarettes, confectionery and morning and afternoon teas. Up to several hundred children travelled by train to Kurow each day for schooling. While the families were more centred on 'home' life, the single men made much



A panorama of the Waitaki dam site in May 1930, showing the huge public works camps, the two trestle bridges across the river, and on the Canterbury side the coffer dams within which dewatering and dam foundation work is starting.
AJHR, 1930, D-1

use of the hall and the sports ground and its buildings. There were many concerts, dances, movies, card evenings, debates and political meetings in the hall. Although the consumption of alcohol was traditionally forbidden in public works camps, a certain amount of home-brewing did occur.

Because of the size of the camp and the presence of considerable numbers of salaried permanent staff, social divisions were more marked than in smaller camps. To some extent there were also divisions between families and single men.

As well as the permanent Public Works Department staff, there were the 'Reg. 130 men', employed on an hourly basis but in fact often working long-term for the department, and temporary staff. Below these groups were the unskilled manual labourers, who did much of the pick and shovel work, as well as carpenters and other tradesmen. The manual workers worked in gangs on the 'co-operative contract' system.

Working conditions were not good. Three men drowned, eight others died as a result of accidents, and there were many other injuries. By the end of the project there had been 1,864 compensation payments for death or injury, accounting for 1.6 per cent of the total cost of construction. There were few safety precautions, and on average one accident occurred each day; it was said that in one year alone there were some 540 instances of injury. Men had to work in near-freezing water, under unstable shingle, and with faulty gear and unsafe machinery.

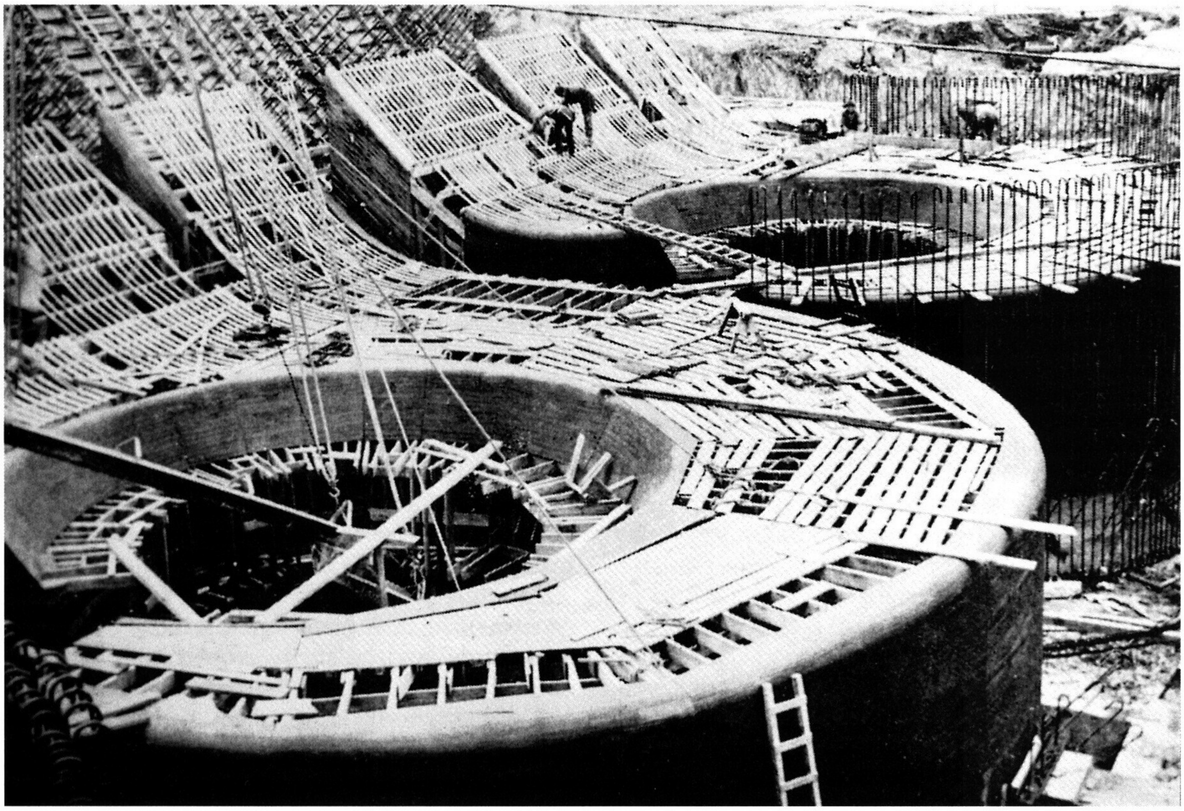
There was a doctor at Kurow, but those requiring hospital treatment had to travel to Oamaru. A Waitaki Hydro Medical Association, to which the men paid a monthly subscription deducted from wages to cover doctor's and hospital fees, was formed in 1928. The association had an agreement with the local doctor and the hospital to provide services in return for a proportion of its income. The Public Works Department also contributed by way of compensation payments. Membership of such associations was subsequently made compulsory by the department, and in 1937 the Waitaki association merged with the newly formed New Zealand Public Works Workers Medical Association.

In February 1929 Dr D. G. McMillan took over the local surgery: 'Young, enthusiastic, idealistic and full of energy . . . he served with a will. Regarding himself as on call 24 hours a day . . . he was willing to tackle anything.'[4] McMillan remained until 1934. Like the Rev. Arnold Nordmeyer, the local Presbyterian minister, he became a member of the first Labour government in 1935. McMillan's proposals for a national system of free health and hospital services for all had been adopted as Labour Party policy. He chaired the parliamentary select committee that investigated such a scheme and whose recommendations formed an integral part of the Social Security Act 1938, which provided for heavily subsidised general practitioner services and free public hospital care among other things. The origins of this aspect of the welfare state lay in the Waitaki Hydro Medical Association.

The engineers had designed an open-construction low-head dam with a compound, curved, overtopping spillway and a powerhouse by the right abutment. Because of the low head, the turbines were very large in relation to the power generated.

The first major step was the creation of a narrow island coffer dam in the river between the two trestle bridges in the winter of 1929, by driving in sheet piling and then building within it part of the dam. Electric and steam-driven pumps worked continuously to remove water from the works. At this time more than 300 men were employed. In 1930, with 1,000 men working on the project, the section between the coffer dam and the Canterbury side was enclosed by steel piling, and more of the dam was built to a safe height as quickly as possible. Eleven openings were left as sluices for the river. The Otago side of the dam, the construction of which was planned for the winter of 1931, was to be built inside a third coffer dam.

In October 1930 Hörnell visited the site. One of his major concerns was the recently appreciated question of the effect of water under pressure infiltrating under the dam's structure. He thought that insufficient attention had been paid to leakage under the dam, and made suggestions for improving drainage. As a result, the so-called 'Hörnell Gallery' was subsequently added to the upstream face, to collect water from the dam and its foundations. The cut-off wall upstream was also deepened to below the bottom of the foundations in order to avert uplift pressure from water that might enter, and the toe of the dam was extended and flattened. (Pressures continued to be monitored constantly, and from 1959 to 1961, as a precautionary measure, the dam was tied down by pre-stressed wires installed from the crest through the structure and anchored in the foundations.)



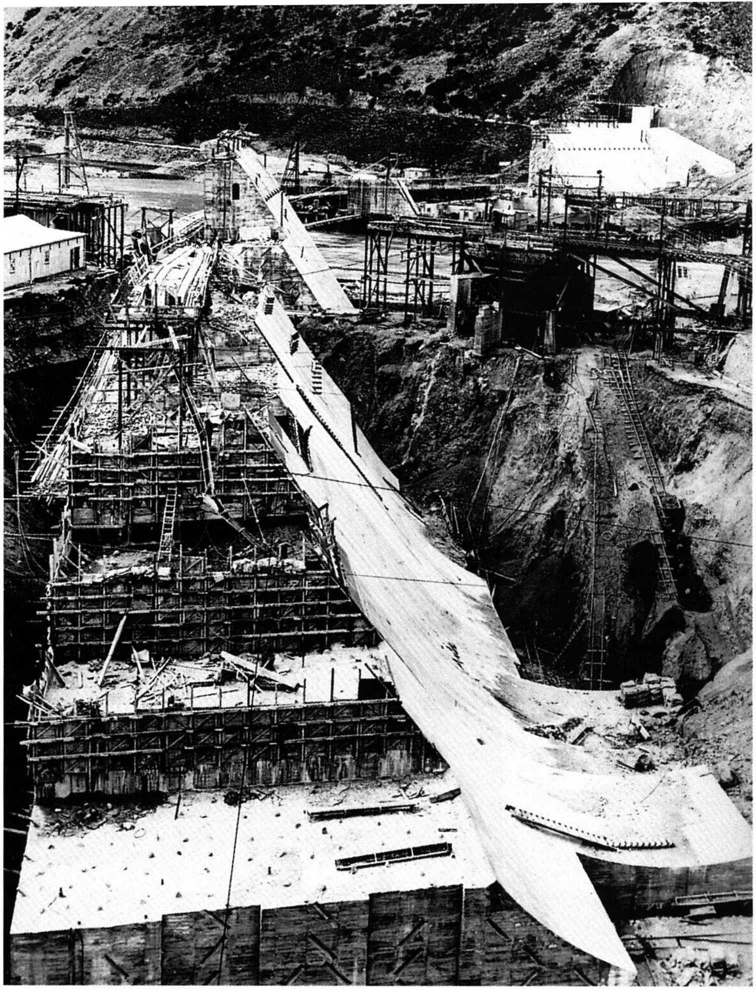
As the Waitaki powerhouse progressed, one of the first jobs was to cast the concrete penstocks and scroll-cases, shown here with the timber formwork in place and steel reinforcing rods being installed.
AJHR, 1931, D-1

Considerable delay was caused by the largest flood in 50 years, which on 3 February 1931 carried away the trestle bridges, damaged the coffer dams and flooded working areas. It was also found that supposed good rock on the Otago side was in fact of poor quality. This necessitated more excavation and concreting than had been allowed for. As the Depression deepened in 1931 financial constraints also slowed down the project, with the work-force cut back from its peak of 1,230 to about 1,000, and wages and salaries reduced by 10 per cent. A reduction in the demand for electricity contributed to a lack of urgency. All these factors resulted in a decision not to try to bridge the river that winter, but to work on the Otago side away from the river channel.

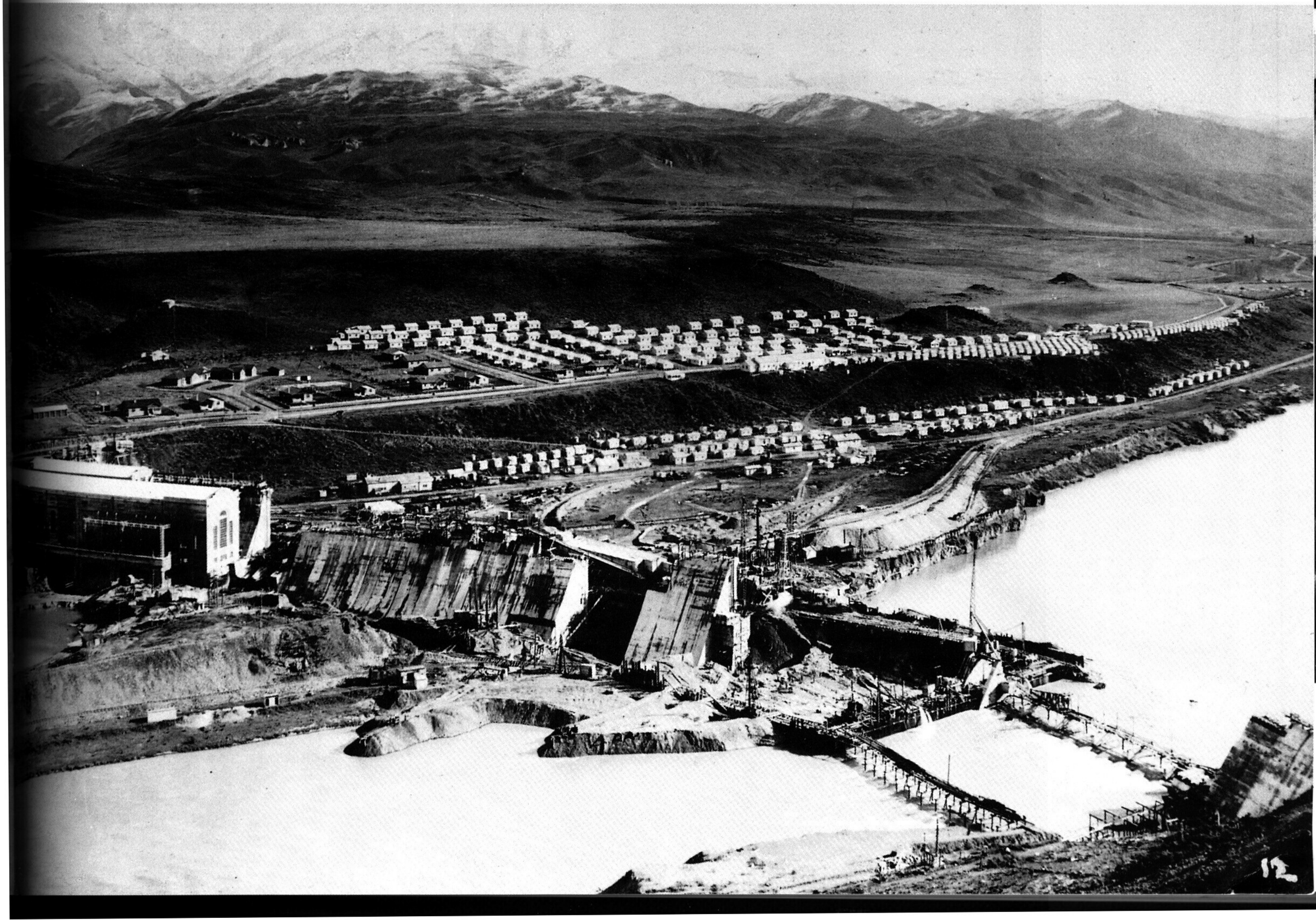
In 1931 the total expenditure on public works was slashed from £8.4 million to £4.8 million, although the amount devoted to hydro-electric development actually increased slightly from £1.2 million to £1.3 million, almost all of which went to Waitaki. Elsewhere, men were laid off and then re-employed as relief workers, and working and living conditions deteriorated considerably. Waitaki was the last bastion of 'standard' public works where the pathbreaking agreement of 1920 still applied, and the only major public works project of the Depression period, but eventually unemployment relief work was introduced even there.

In 1932 wages and salaries were cut again, and the numbers employed in the Public Works Department as a whole were reduced by 40 per cent. Expenditure on public works was again savagely cut, this time to £1.7 million, with a mere £500,000 devoted to hydro-electric works. In June the work-force on the site was more than halved to about 500, mainly by dispensing with single men, and all major excavation work ceased.

However, the Public Works Department was acutely aware of the risk of serious flood damage while Waitaki was left in an incomplete state. The project's vote was increased, and in April 1933, 400 relief workers were employed, so that the numbers on site increased to 900. As the Engineer-in-Chief reported in general: 'to assist in the relief of unemployment manual labour is being utilized where practicable, and reasonably economical, in preference to excavating machinery.'[5] Coates' policy of mechanisation had thus been reversed. Under these conditions the New Zealand Workers' Union found it impossible to make headway. Its membership had fallen by more than half and it was in considerable financial difficulties. Even at Waitaki, where the agreement still applied to some of the work-force, the union asserted bitterly that the project would 'go down in history as one of the blackest Public Works

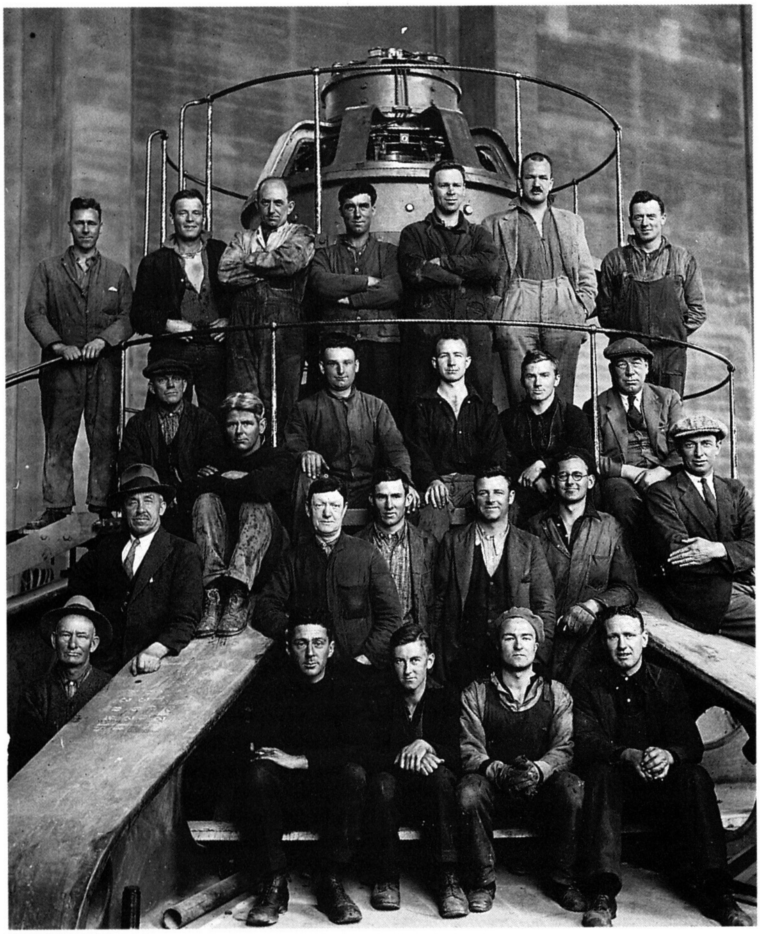


Right: By October 1932 a substantial part of the Waitaki dam had been built, both on the Canterbury side in the distance and, in the foreground, on the Otago side away from the river channel. This photograph shows clearly the separate construction blocks in which the dam was built. The river still flows through the middle of the emerging dam.



Below: A wintry scene at Waitaki Hydro in 1933. By this time the Canterbury side (bottom right corner) had long been finished, as had the Otago side away from the river channel and the powerhouse itself. The gap remained to be bridged, the most difficult part of the job since the dam was to be built without a diversion channel. The central section was completed during the winter while flows were low, the river being diverted through temporary sluices in the Canterbury side of the dam.

Workers take a lunch-break and warm themselves around a brazier. The Waitaki site was windswept and extremely cold in winter.



undertakings in New Zealand so far as unionism is concerned'.[6] This statement was made after no improvements in working conditions had resulted from an enquiry the union had demanded.

By June 1933 the Canterbury side of the dam was sufficiently complete for the river to be diverted through the temporary sluices, and another coffer dam was constructed on the Otago side. The first two generators were installed in that year. This work was undertaken with some urgency, as the sluices were unable to cope with peak flood conditions. The sluices were closed and concreted up during the winter of 1934. Despite the fact that three sluice gates over-ran their positions and proved difficult to seal properly, the lake was filled in September 1934 and turbine testing started.

Sealing of the troublesome gates and infilling of the sluices proved to be complex. This work was not completed until 1936, and required an ingenious solution using a contraption known as the 'mouse-trap', which had a large pipe surrounded by framework, to take the flow; this device was inserted up the sluice to allow concreting. In order

The generator-erection team pose on one of Waitaki's vertical-shaft Francis turbines.

to carry out this delicate manoeuvre, a smaller box known as the 'submarine' was built, in which lay a man, encouraged by part of a bottle of whisky. He was hauled up the sluice to attach a pulley and rope with which to haul the 'mouse-trap' in.

Waitaki was officially opened by the Governor-General, Lord Bledisloe, on 27 October 1934. Several thousand people arrived by special trains and by car to witness the sight of the flood of water roaring over the spillway and being broken up by the disrupters before plunging again into the river. Waitaki initially produced power at 66 kV to be compatible with Coleridge. Full power at 110 kV was available from the two machines from the beginning of 1935, after lengthy testing of the generators. These were physically the largest employed in New Zealand up to that time and, because of their size, could not be tested completely until the lake filled. Dunedin agreed in 1935 to take power from Waitaki rather than rely on the expansion of Waipori. Lines now linked Coleridge, Waitaki and Waipori. By the end of the 1930s most of the South Island's population outside the Nelson-Marlborough region was served by a single system.

Waitaki's initial capacity of 30 MW could satisfy about half of the existing South Island demand. A third machine was added in 1940, and another the following year at a time of considerable wartime power shortages. This capacity kept the South Island going for a time. However, Waitaki was basically dependent upon run-of-river water and, because the river was snow-fed, this was erratic. The station could be run on all four generators from its headpond for a few hours only, a matter of considerable concern. The original planned capacity of 75 MW became available in 1949 with the installation of the last machine, and two further machines were added in the extension to the scheme built between 1952 and 1954, in association with the controlling of Lakes Pukaki and Tekapo. This allowed capacity to be increased to a final 105 MW, and helped satisfy South Island demand until Roxburgh was finished in 1956.

Other South Island schemes

Arnold

After a ratepayer poll approved a loan, the Arnold hydro-electric station at Kaimata on an 'S' bend in the Arnold River was built by the Grey Electric Power Board to replace a small coal-fired station near Greymouth. Construction of the scheme began in October 1929, and the plant was commissioned in September 1932. Lake Brunner supplies a reliable year-round flow, so the dam simply provides a head for the plant rather than water storage. The government bought the plant in February 1938, and the head was then increased by the addition of automatically tipping gates on the spillway. Because of the reliable flow of water, Arnold is in constant use apart from an annual two-week shutdown for overhaul. Also in 1938, the Lyttelton diesel plant was shifted to Dobson to help out until the West Coast could be linked with the South Island network. This was in fact used until 1958, even though a 66 kV line had been put through in 1939.

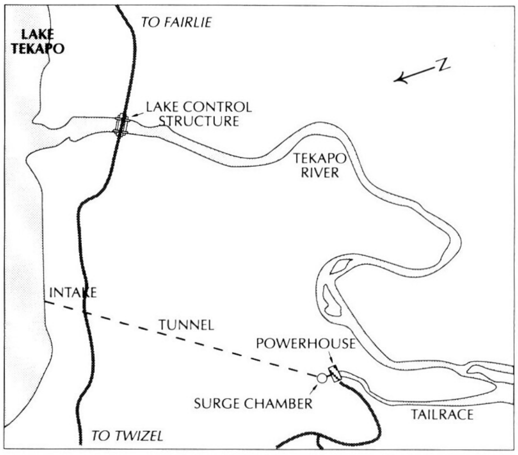
Arnold: Constructed 1929–32. Head originally 36 feet, later extended to 42 feet. A concrete gravity dam with an earth wing wall. A tunnel 11 feet in diameter and a conduit 1,650 feet long lead to a surge chamber and a powerhouse via two short penstocks. The station had the first variable-pitch Kaplan turbines in the Southern Hemisphere, driving two 1,500 kW generators. Total capacity is 3,000 kW.

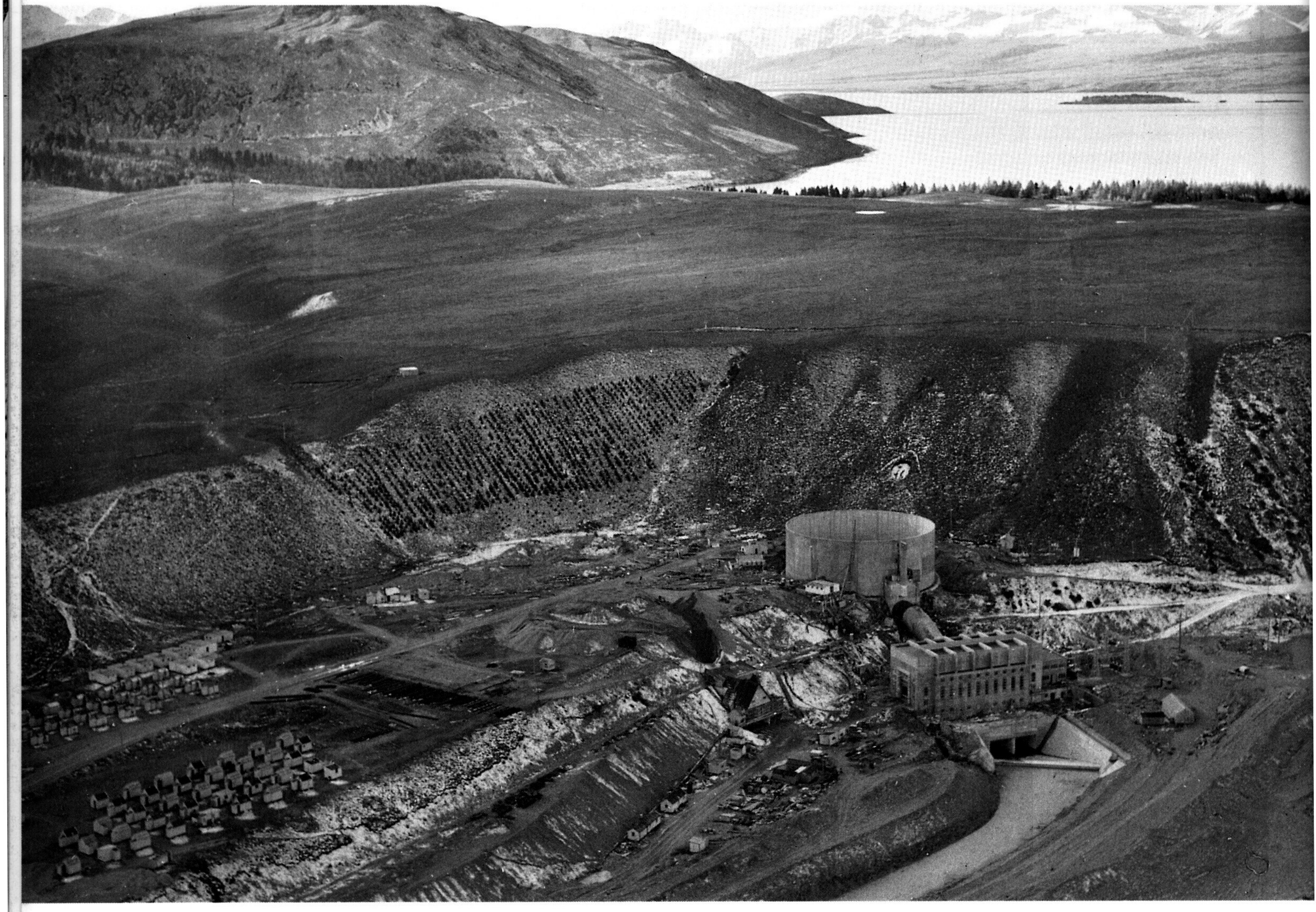
Tekapo A

Control over the level of Lakes Tekapo and Pukaki was especially crucial because of the peak spring and summer flows.[7] It was clear that there could be much more development of the Waitaki, and a number of options had been considered in the mid-1930s, ranging from diversion of the waters of Tekapo under the Two Thumb Range to the simple expedient of installing a plant without control works at the lake outlet. Between these extremes a number of dam sites were considered, as was the possibility of complete control of the lakes. At that time cottages were being built near the Tekapo outlet, and this gave rise to a good deal of agitation against interference with the lake levels. Kissel argued that the department should develop a definite scheme quickly and seek approval for it. This was soon done, and a small station on the bank of the Tekapo River and a control structure at the lake outlet were built.

Work began in 1938 with a completion target of 1943, but because of the war, construction was discontinued in 1942. Work resumed in 1944, and a large camp with a population of more than 500 was established. The tunnel, which carried water

Tekapo A: Constructed 1938–51. Head 100 feet. A 6,000-foot-long tunnel, 20 feet in diameter, takes water from the lake to a large cylindrical concrete surge tank, penstock and powerhouse with a single Kaplan turbine (used because of the low and varying head) and a generator of 25.2 MW. The Lake Tekapo control works were constructed from 1951 to 1953 and involved a reinforced-concrete buttress dam, 45 feet high and 325 feet long, across the outlet to the lake, with four sluice gates. The Pukaki lake control works were built in the period 1946–51. They comprised a 73-foot-high rolled-earth-fill dam with a silt core and compacted gravel shoulders, and a control-gate and spillway structure with six gates.


LAKE TEKAPO
TO FAIRLIE
N
LAKE CONTROL STRUCTURE
TEKAPO RIVER
INTAKE
TUNNEL
POWERHOUSE
SURGE CHAMBER
TAILRACE
TO TWIZEL

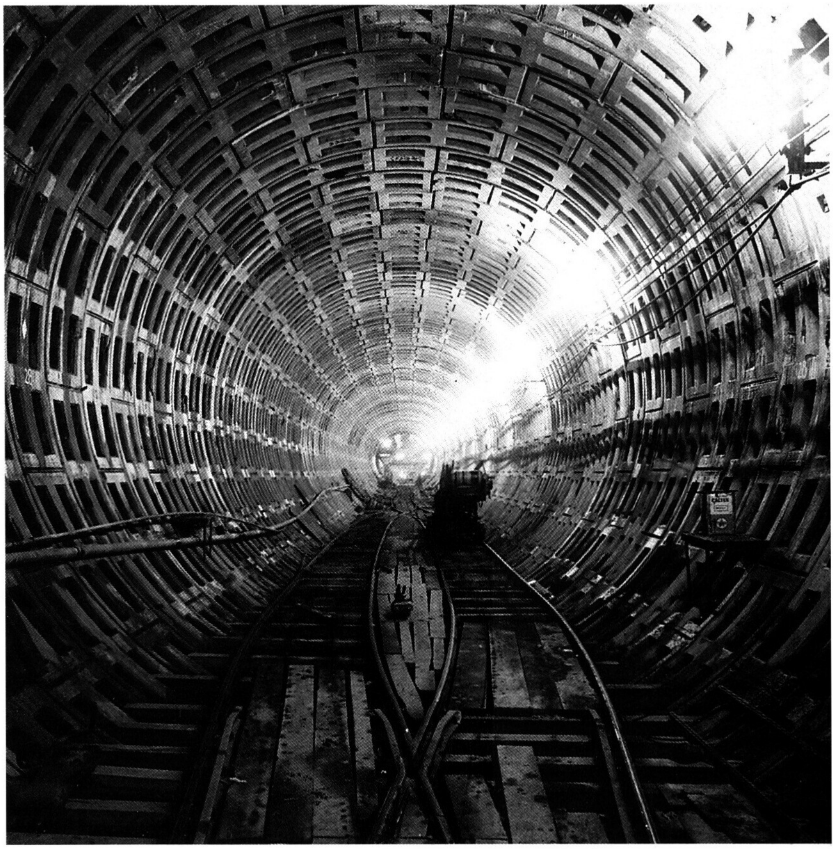


from the lake to the station through glacial moraine, was particularly difficult to construct because of the unstable material and water. As a result, a method previously untried in New Zealand was used, with two steel shields 23½ feet in diameter being thrust forward by hydraulic jacks as each end of the tunnel was excavated. The tunnellers worked on platforms in front of the shields, and the spoil was removed by conveyor belt.

By early 1948 the tunnel had been two-thirds driven, and after considerable difficulties it was holed through in October of that year. Because of the conditions, the tunnel was first lined with many thousands of reinforced concrete blocks before being lined with cement. Some 600 feet of the surge-tank end of the tunnel was lined with steel, a job completed by 1950. The scheme was commissioned in June 1951 before the level of the lake had been controlled.

After the station began operating, Lake Tekapo was raised by 15 feet and regulated over a range of 25 feet by control works. This work was started in 1951 and completed by December 1953. Seepage through the glacial deposits was controlled by cut-off walls under the concrete dam.

Meanwhile control work had started at Lake Pukaki in 1946, having been brought forward because of the difficulties with Tekapo A. The lake was raised and controlled over a range of 30 feet by an earth dam, which by 1948 had been sufficiently built up to store water. Completed by 1951, it was the first earth dam of this type built by the Public Works Department.



Right above: The Tekapo A tunnel was driven through glacial moraine with great difficulty, and required lining with many thousands of reinforced concrete blocks.

Right: The night shift in the Tekapo tunnel 'brews up'.
Hydro-electric Power, State Hydro-electric Department, c. 1949

Opposite: The Tekapo A power station near the outlet from Lake Tekapo used a single large variable-pitch Kaplan turbine because of the varying head provided by the lake. A tunnel just over a mile long delivers water into the large surge chamber above the powerhouse, and the water flows into the river after going through the turbine.
Whites Aviation

Highbank

Highbank drew water largely from the Rangitata River, and was designed around the Ashburton County Council's plan to provide irrigation between the Rangitata and Rakaia Rivers. The department undertook the work. An irrigation race with a capacity of 1,000 cusecs was designed with control gates that could be closed to allow the head between the two rivers to be used for electricity generation. This scheme took advantage of the different requirements of irrigation and electricity generation, and was an excellent early example of multi-purpose development.

Work on the powerhouse on the south bank of the Rakaia was begun before the war, and it was hoped to generate power by 1941. However, the irrigation race was not completed until 1944, and the station not until 1945, after seepage around the head-gate structure had created difficulties, and floods early in 1945 necessitated the relocation of the village and construction of a new approach road.

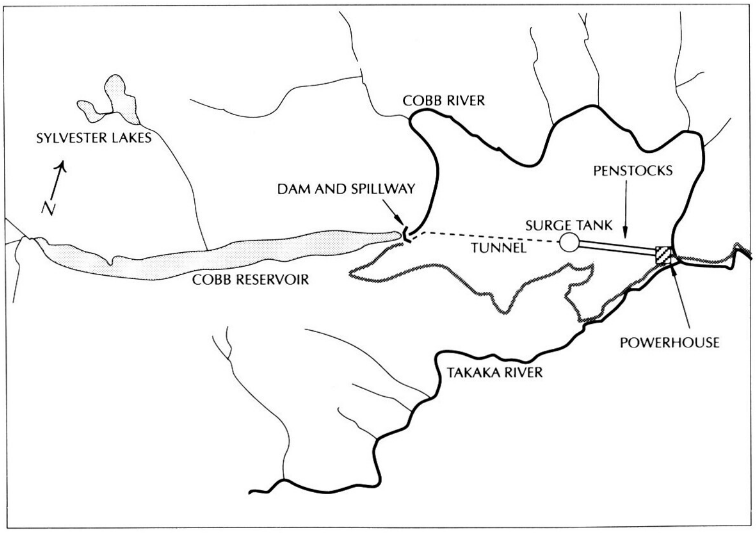
Over many years sand from the Rangitata River accumulated at the end of the race, reducing the station's output substantially. From 1976 to 1979 large quantities of sand were dredged and a sand-trap was installed near the beginning of the race to prevent a recurrence of this problem. The original intention was to generate power mostly in winter when the water was not required for irrigation, but in practice water has usually been available and the station has been run extensively throughout the year.

Highbank: Constructed 1939–45. Head 330 feet. Water is taken from the end of the Rangitata diversion race (used for irrigation) and drops down from a river terrace in a single penstock to the powerhouse on the bank of the Rakaia River. The penstock is supported on roller bearings to allow expansion. The water drives a single turbine and generator of 25.2 MW, which at the time of installation was the largest single unit in operation.

Cobb River

For many years people in the northern part of the South Island and on the West Coast were left to their own devices so far as electricity supply was concerned. Marlborough chose to go its own way with a station on the Waihopai River supplemented by diesel. The Nelson City Council was at first unenthusiastic about hydro-electric

Cobb River: Constructed 1937–44, extended 1949–54. Its head, at 1,950 feet, is the highest of any hydro-electric station in New Zealand. A concrete pipe and tunnel, more than 1½ miles long, leads from the upper Cobb Valley to a surge chamber and then to a steel penstock, 6,850 feet long, which drops to the powerhouse in the lower valley. The water initially drove four horizontal Pelton wheels and 3,000 kW generators. Later extensions included an earth dam, 107 feet high and 725 feet long, which forms a lake in the upper Cobb, an additional penstock and two more 10,000 kW Pelton-driven machines. Total capacity is 32 MW.



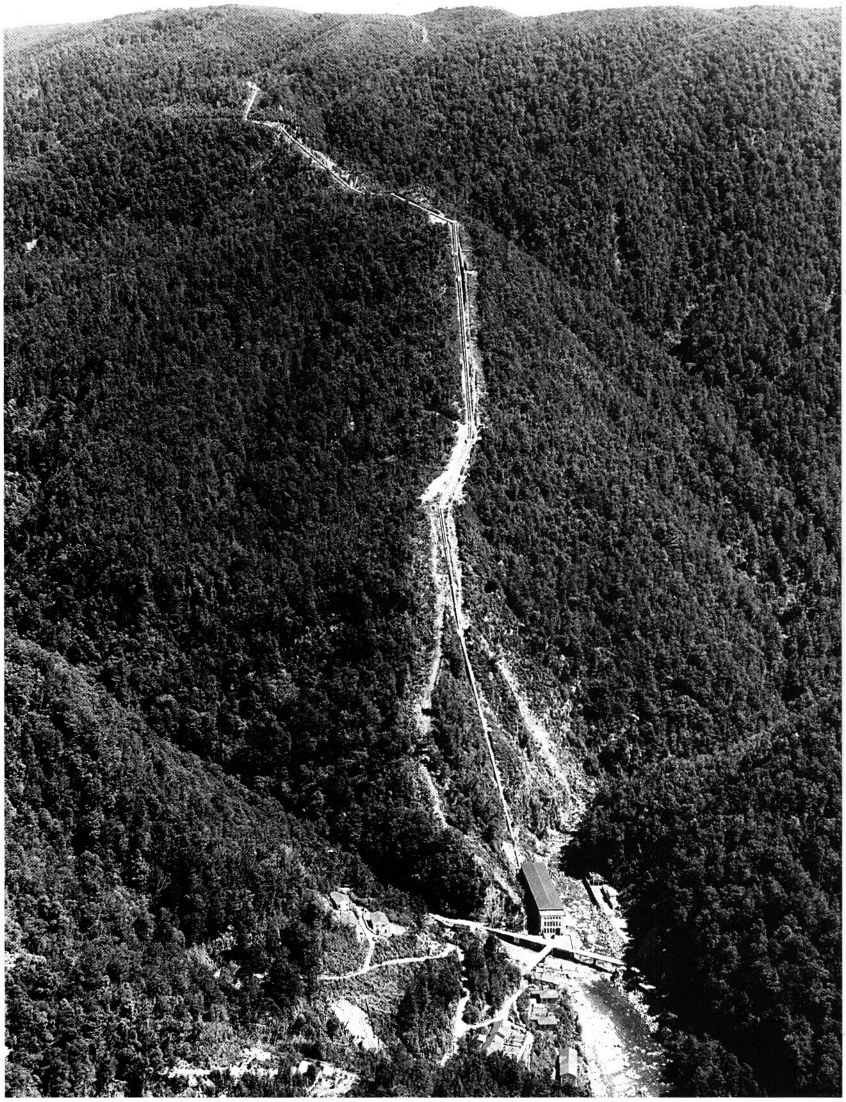
development, preferring its own steam plant. There was some consideration of the Gowan River (the outlet from Lake Rotoroa) by the Public Works Department, but any scheme there would have produced more than twice what the area could consume. The basic problem was the lack of a large load centre.

The Hume Pipe Company — an Australian firm whose New Zealand interests were in asbestos mining and manufacturing — saw both the opportunity and the department's reluctance to meet it. The company was itself a large user of electricity — its diesel plant could produce well over twice the amount of power used in Nelson city — and it had a strong interest in mineral extraction in the Takaka-Collingwood area. It came up with a scheme to construct a station on the Cobb River. The site had been chosen to take advantage of the fact that above it the river dropped nearly 2,000 feet in a direct line of less than three miles, which meant that each cusec could generate a large amount of power. The water would be brought through a tunnel driven in the ridge between the Cobb and Takaka Valleys, and then dropped through steel penstocks to the powerhouse.

The government could not easily reject this plan, given that it did not itself intend to act, and the company was in July 1935 awarded a licence for 40 years, at the end of which the works would pass to the Crown, which meanwhile would retain the right to purchase. After a certain amount of ideological discomfort the licence was confirmed by the incoming Labour government, but things soon went wrong. The Hume (Cobb River) Electric Power Company failed in an attempt to raise capital from the public in 1936, and later efforts to extract further funds from shareholders were also unsuccessful. The company never had more than half the finance needed to see the project through.

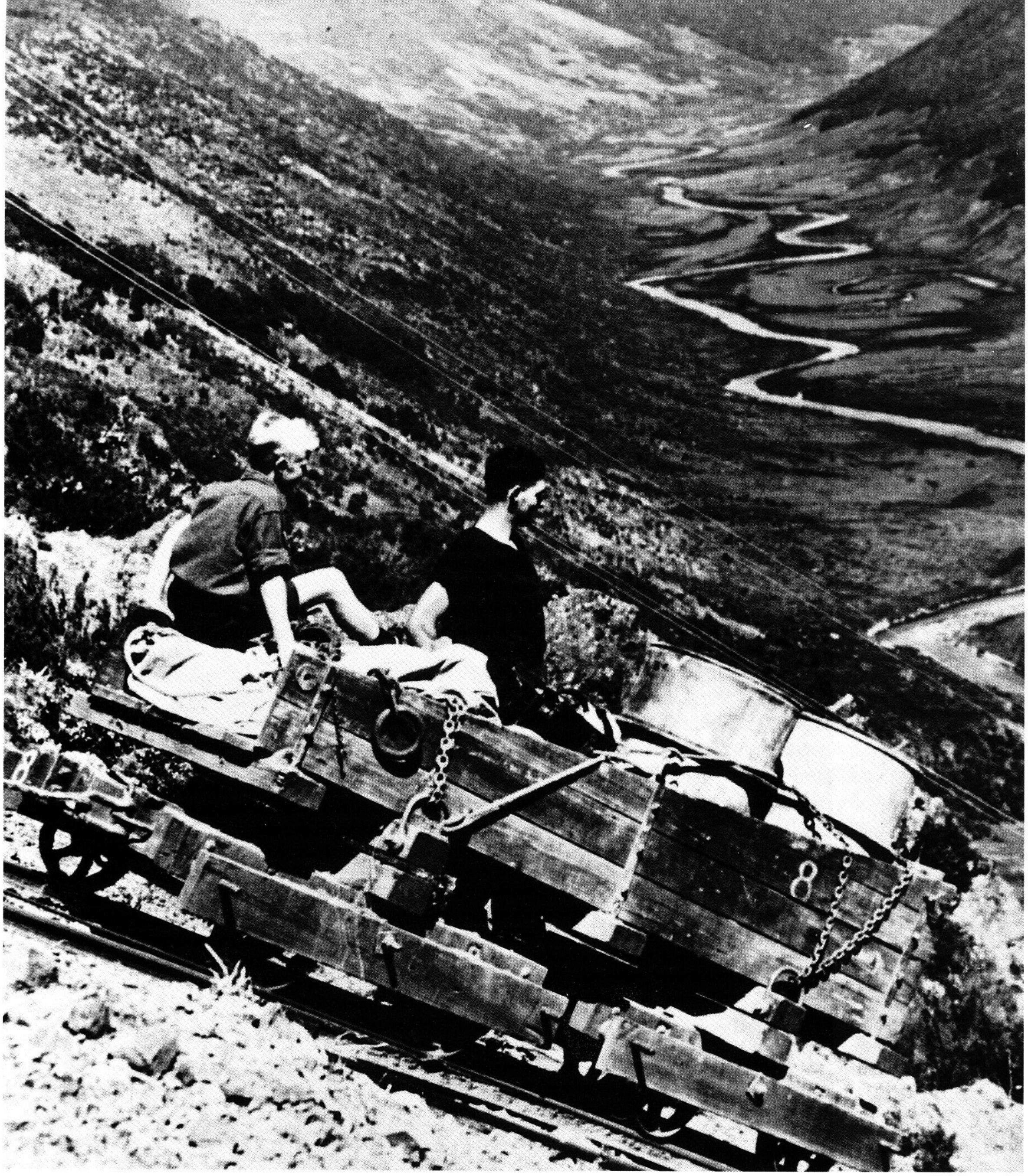
In 1937 the difficult work of building the access road from Upper Takaka to the powerhouse site at the junction of the Takaka and Cobb Rivers began. Early access to the tunnel intake and the proposed dam site was by a series of six jigs — skips that ran on light rails and were drawn by winches and wire ropes over the 3,000-foot-high Mount Cobb and down into the upper valley. This must have provided thrilling, even fearsome, rides. In 1938 several approaches were made to the government for loans, investment finance or the meeting of costs such as roading. All were rejected.

Late in 1938 W. R. Hume himself came to New Zealand and asked the government to underwrite an issue of debenture capital that he claimed would see the scheme through. Walter Nash, the Minister of Finance, rejected this proposal and made it clear that if the company could not complete the project, the government would take it over. This duly happened in 1940. By then a



The Cobb River scheme involved taking water from the upper reaches of the Cobb River, through a tunnel and down long steel penstocks to the powerhouse nearly 2,000 feet below at the junction of the Cobb and Takaka Rivers, yielding the highest head in the country. The scheme was the mainstay for the region but it suffered from a lack of storage, so an earth dam was built and the powerhouse was extended (shown here).

National Publicity Studios collection, Alexander Turnbull Library



powerhouse for four units was complete, but it took another four years of struggle with wartime shortages of labour and materials before the station produced any power. The first power for the Nelson area came in June 1944, and for Marlborough in January 1945.

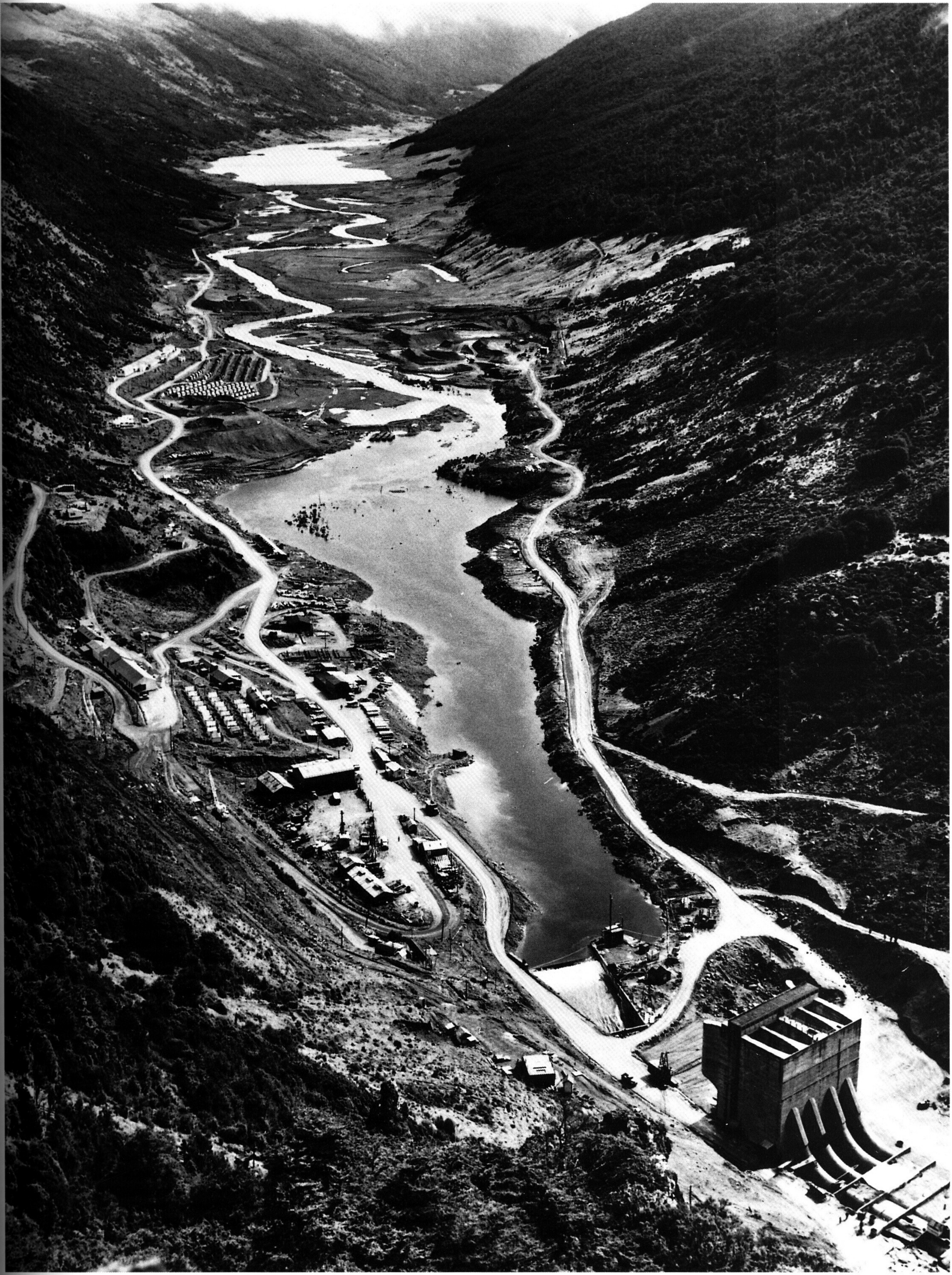
The initial plant was simply a run-of-river station with a low crib log weir diverting the water through screens and into the tunnel, and providing a little storage. Power was transmitted to several substations: Motupipi for the Golden Bay Power Board and the cement works at Tarakohe; Motueka for the Waimea Power Board; and Stoke for Waimea, Nelson and later Blenheim. The Cobb River plant, supplemented by other

Above: Access to the upper reaches of the Cobb River was possible only by means of jig-lines and skips drawn by winches and wire ropes, as shown here *c.* 1939. These provided thrilling, even fearsome, rides. In the background the river in its original state can be seen.

Making New Zealand collection, Alexander Turnbull Library

Opposite: Originally there was little or no storage at Cobb, but, as part of extensions to the scheme in the early 1950s, an earth dam and concrete intake, shown here under construction, were built in the upper river valley. Public works camps can be seen a short distance up the valley, which is now a lake.

New Zealand Forest Service collection, Alexander Turnbull Library



small stations, was the mainstay for the entire Nelson-Marlborough region. With the station almost solely dependent on river flows, there were problems in both summer and winter. Staff became adept at teasing water out of small lakes in the Cobb catchment, and in topping up the weir with sandbags to give a little more storage.

If a reservoir was built, capacity could be extended considerably. The company had assumed that the Cobb could be dammed quite easily once access was gained. The department believed that things were not so simple, and this proved to be the case. Large-scale excavation had to be done before it became clear that the rock was unsuitable to support the concrete gravity dam that had been intended. A substitute earth dam was built between 1949 and 1954. Because of the desperate need for power at that time, a new larger powerhouse to house the additional machines was built over the original structure so that the station could be kept going during the extensions. The expanded Cobb River scheme had a capacity of 32 MW, which finally became available in 1956 after serious delays, largely because of labour shortages while the dam was being built.

However, by the early 1950s it was becoming evident that even an expanded Cobb River station would not suffice, and the department investigated other possibilities. The Braeburn scheme, using water from Lake Rotoroa, was formally approved in 1952, but deferred a year later and dropped in 1955. The cost was too high — a very long tunnel would be needed to take water from the lake to a powerhouse in the Mangles Valley — and advances in the technology of high-voltage transmission were making it more practicable to obtain power from the main South Island system. The region was soon linked into the wider system, first by the 110 kV Stoke-Inangahua line in 1956, and then by the main 220 kV Islington-Kikiwa line in 1959.

PART THREE

Consolidation & Corporatisation 1946–1998

CHAPTER SIX

Planning for Demand

PARRY'S GOAL of making about 150 watts capacity per head available throughout New Zealand had become a reality by the 1930s. Large-scale hydro-electric schemes made electricity both much cheaper in real terms and much more widely available. At the same time competitors such as coal and gas rose in price.[1] Supply authorities worked hard to increase load. The bulk tariff, which was based on peak demand, provided a strong incentive to create new off-peak uses such as controlled domestic water heating and (later) storage heating.

The 1920s: electricity takes off

The 1920s marked the take-off in demand for electricity in New Zealand and the beginning of the familiar pattern of demand outpacing supply that has existed until recently. During this decade, units generated rose by 22.2 per cent per annum on average. Over the decade the units consumed increased sevenfold, the number of consumers fivefold, and route-miles of line more than sevenfold as the transmission system was developed. The number of units sold per capita rose by three and a half times, much of the increase coming from new consumers.

Electricity was now firmly established as a marketable commodity. The question was whether the government's construction of power stations could keep up with the escalating demand. In response, capacity increased fivefold during the 1920s. As in other countries the goal was to achieve economies of scale by using increasingly large generating units located at the source of power, in this case water, and high-voltage transmission to load centres, making strenuous efforts to create mass consumption through 'load building' and allowing supply to create demand, interconnecting plants to optimise their different characteristics, and interconnecting loads to increase diversity and raise load factors.[2]

Parry had anticipated these massive changes, and the government's expenditure on Mangahao, Arapuni and Waikaremoana, and on transmitting electricity to major population centres, was wise indeed. Almost the entire increase in generating capacity in the 1920s was due to these three hydro-electric developments, the inclusion of Horahora in the system and the extensions to Coleridge. In 1920 gas, steam and oil plants made up 47.6 per cent of New Zealand's total capacity and generated 28.2 per cent of its electrical energy. By 1930 these figures had plummeted to 18.4 per cent and 8.2 per cent respectively, and they were to fall further as more hydro-electric stations were built in both islands. The complete domination of electricity generation by hydro-electric power was to last until the late 1950s.

Electricity began to transform manufacturing, farming and domestic life. With the incentive of cheap power from Lake Coleridge, Christchurch manufacturers rapidly adopted the versatile and compact electric motor in preference to large steam engines. This reduced the level of capital investment that was necessary, minimised the labour required for tending and maintenance, and eliminated the need for complex systems to transfer power around factories from a central source by shafts, pulleys and belting. Electric motors could be made in a great range of sizes to suit different needs, and could be attached directly to machines. They were clean, much less bulky than steam engines and could be simply switched on when required. By the 1930s virtually all motive power in Christchurch was derived from electricity and many tasks had become more mechanised, particularly in engineering, clothing and freezing works.

Throughout the country large railway engineering workshops were reorganised and rebuilt to use electricity in the mid-1920s. Freezing works also became particularly heavy consumers of electricity for both motive power and water heating. In the early 1930s the assembly-line chain system, which was dependent upon electric motors, was adopted. Smaller workshops also became extensively mechanised. By this time the horsepower of electric motors used in industry exceeded that of steam engines, and close to 90 per cent of motors were electric, which shows the extent of the proliferation of smaller, decentralised power sources that was so encouraged by the adoption of electricity. Electricity was also applied to new processes such as electrolysis and the electric arc furnace.

The battle with gas over street lighting, which had been going on since the 1880s, was settled in the 1920s with the arrival of cheap bulk electricity. The early twentieth century was also the golden age of trams, following their electrification in the major centres in the first decade of this century. Trams dominated city streets and conveyed many thousands between work and the burgeoning suburbs, which depended on this rapid and efficient form of transport. Trams were also crucial for emerging new forms of mass entertainment and leisure. Nothing could match them for cheapness, reliability, speed and quietness. With the introduction of electricity, routes were rapidly extended and more trams used as local authorities took over the services and passenger demand increased.

Electricity had been used first for public lighting and later for industry. Domestic use now became increasingly dominant. A high proportion of domestic consumption and a lack of large-scale electricity-intensive electrochemical and electrometallurgical industries have been features of New Zealand's use of electricity compared with other countries. In the 1920s, however, domestic consumption was largely limited to lighting, and ironing from a specially adapted 'ironing point'.

Extensive additional wiring was needed if a home was to have water heating and other appliances. Electricity was fighting a real battle with gas on the cooking front at this time, with gas ranges still greatly outnumbering and outselling electric ones. Electric ranges were manufactured in New Zealand from 1925, when Shacklocks of Dunedin produced their first 'Orion', but the great majority were still imported.

Once the householder had decided to buy an electric range and have the necessary wiring done, the floodgates were opened for other increasingly available appliances, the only constraint being cost. By the late 1920s many electric ranges were being installed and other appliances, whose cost was dramatically dropping, were increasingly used. The first 'All-Electric Exhibition' was held in Wellington in late 1929, with a large number of importers and retailers displaying all the latest household appliances. By 1930 about 26,000 electric ranges had been installed, largely in better-off homes. One of the most dramatic increases in the domestic consumption of electricity came with the adoption of electric water heating. The insulated storage water heater with immersed element had been developed by Lloyd Mandeno in 1915. By 1930 nearly 38,000 had been installed in New Zealand homes.

The 'all-electric' home, it was said, would relieve women from domestic drudgery and replace the domestic servant with the 'electric servant'.

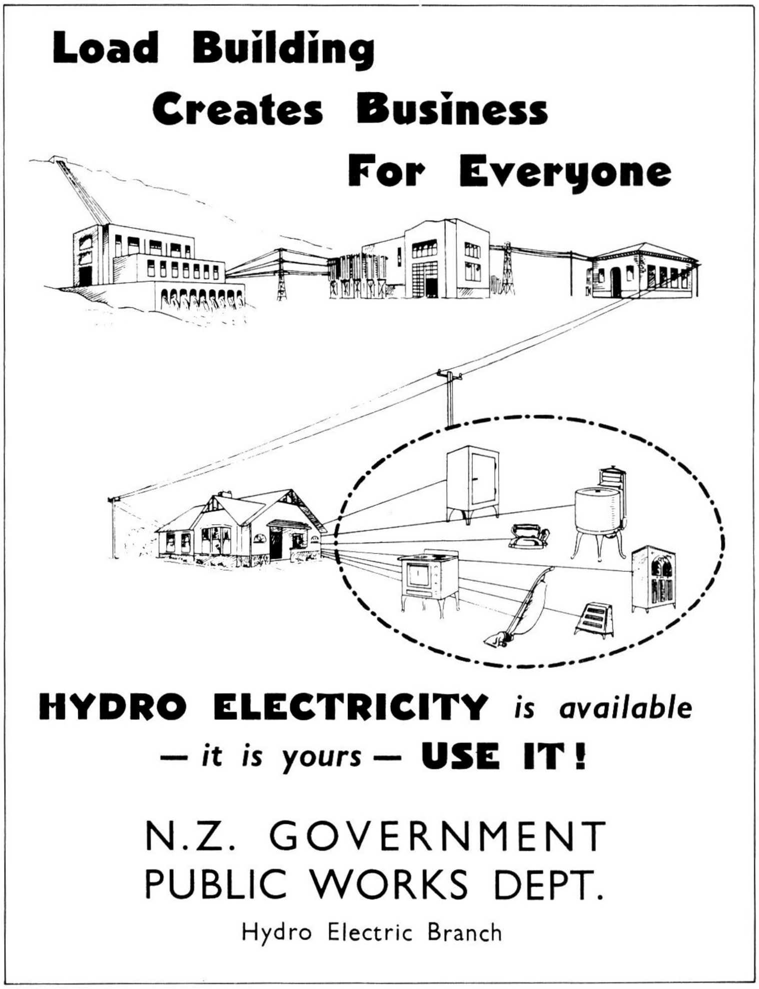
> Women's work under the old methods was 'never done'. Her position in the home was that of domestic drudge, and when the day was well advanced she dragged herself to bed tired. Electricity . . . emancipates the housewife from all the worst forms of domestic drudgery. A mere flick of the switch abolishes for all time the filth and fumes of the old fashioned fires, or stoves, brooms and washtubs. More leisure hours are provided for mental and social recreation and a touch of happiness is introduced that has hitherto been lacking.[3]

The reduction in time and physical labour spent on housework was one factor contributing to the greatly increased numbers of married women in paid employment, along with factors such as the earlier age at marriage and a tendency to have fewer children over a shorter period. Women's paid employment was also encouraged by the wider opportunities offered by a larger industrial sector, which was itself promoted by the availability of electricity.

Electricity was now supplied to a much higher proportion of the population. In the latter half of the 1920s there was a tremendous burst of erection of transmission lines. By 1930 some 45 power boards had been set up, covering nearly two-thirds of all New Zealanders, and more than half of these had extensively reticulated their districts. More than 19,000 route-miles of line had been erected, largely in the more closely settled, well-established and accessible areas. In regions where government-supplied power was not available, such as Taranaki, Southland, Marlborough, the West Coast, Nelson and Golden Bay, power boards operated their own plants. The most dense areas of reticulation were Taranaki in the North Island and Southland in the South, with Manawatu, Wairarapa, southern Hawke's Bay, Waikato, Bay of Plenty, Gisborne, and the Canterbury Plains also extensively covered.

As power boards extended lines into country districts, farms rapidly acquired electric motors to run shearing machines and water pumps. The impact of electricity was felt especially in dairying, which soon came to use electrically driven milking machines in place of those powered by internal combustion engines, particularly in Canterbury, Waikato and Bay of Plenty. The milking machine largely eliminated the drudgery of hand-milking and greatly increased the size of a manageable herd. Electrically heated water with which to sterilise and clean in the shed also became increasingly common, and electricity was extensively adopted by dairy factories. Electricity also transformed the domestic life of dairy farmers. A national survey in 1936 indicated that 80 per cent of farmhouses had electricity connected, and of these, all had electric lighting and an electric iron, and about one-third a vacuum cleaner, electric range and electric hot-water cylinder.[4]

Electricity enhanced lives in many other ways. Steady, bright and clean electric lighting changed the interiors of homes by encouraging much brighter and more cheerful wallpaper and interior decorating. The city nightscape was visually transformed by the introduction of neon lighting. Electricity ushered in the era of 'motion pictures', and in the 1920s the radio emerged as not only a means of entertainment but also an instrument for breaking down the isolation that was felt so keenly in rural areas.

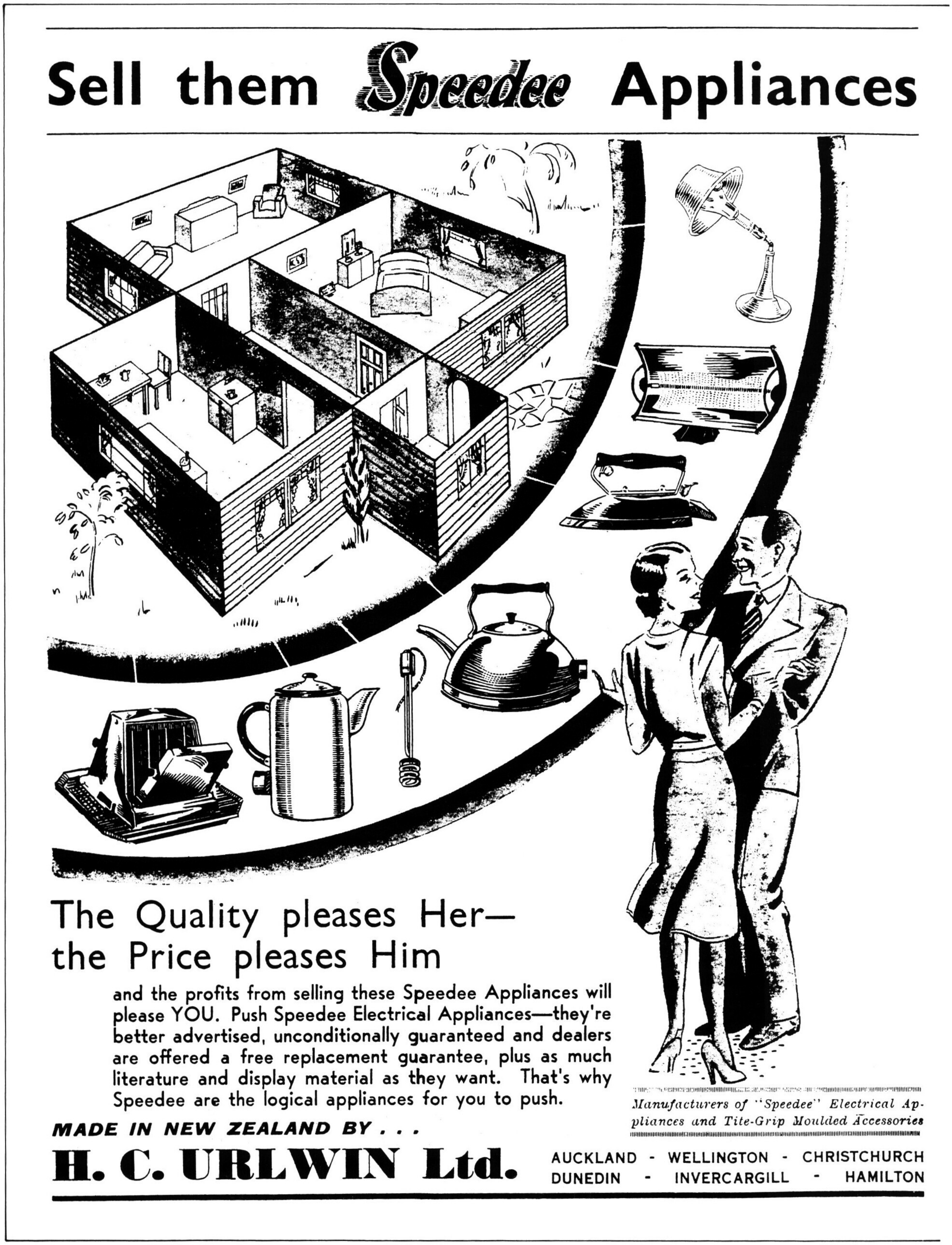


As the country emerged from the Depression the talk was all of 'load building' — selling electricity in a situation of perceived surplus with additional units available from the hydro-electric system at little marginal cost. The Hydro-electric Branch used advertisements such as this in the years 1936 to 1938.
NZ Electrical Journal, 20 September 1936

The 1930s: load building

Even after the country emerged from the Depression there was little impetus to expand capacity, in spite of a return to rapid increases in consumption, particularly in the North Island. The average annual rate of increase had slowed to 5.3 per cent during the period 1930–33, but then had more than doubled to 12.0 per cent per annum up to 1940. The National Expenditure Commission recommended in 1932 that no further hydro-electric works be commenced for many years, and supply authorities remained sanguine about the ability of existing plant to cope with likely demands. Attention was focused on the use and expansion of steam and diesel plants, and the building up of loads.

At this time there were frantic efforts at 'load building': the sale of more power at low marginal cost in a situation of perceived surplus capacity. In 1933 an article in the *Electrical Journal* stated that



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the period had now passed 'when the value of load building was in question . . . the issue [is] . . . that of when, how and by whom'.[5] It urged that suppliers take advantage of the 'huge treasure . . . which the housewife holds locked up in the 250,000 homes throughout New Zealand'. This was to be achieved by extending the use both of water heaters and ranges, the traditional domestic heavy load bearers, and of the many other household appliances not then widely adopted, such as refrigerators, kettles, radios, toasters, vacuum cleaners and washing machines.

In 1935 the supply authorities in vain urged the government to adopt an 'inducement rate', a temporarily lower rate for electricity intended to attract new consumers. They also began agitating for lower bulk-supply charges, arguing that 'surplus' power could be sold by the department at reduced rates.[6] Most supply authorities worked assiduously at building domestic loads by methods that included special advertising, canvassing, easy terms on the sale of electrical equipment, demonstrations, cheap rates, special discounts and free or cheap wiring.

The problems with Arapuni and the high initial capital cost of hydro-electric schemes perhaps inhibited confidence. It was understandable that in monetary terms the level of expenditure of the late 1920s was not sustained during the Depression, although hydro-electric development continued to account for a high proportion of the Public Works vote. But curiously, when Labour came to power in 1935 both actual amounts spent and expenditure as a proportion of the Public Works vote fell considerably. Their reputation for generous public works spending did not extend to construction of generating plants. Labour gave railways and roading a much larger share, while aerodromes, irrigation works and public buildings also received much attention. (A big rise in spending during the 1937 financial year was merely a result of the purchase of the Southland Power Board's assets.) While there was increased spending from 1937, this was still a smaller proportion of the total devoted to Public Works than previously.

With the election of Labour to power, Bob Semple became Minister of Public Works. Apart from a break in 1941–42, he was to retain this portfolio until 1949, together with that of the State Hydro-electric Department when it was established in 1946.

Opposite: A profusion of advertisements extolled the virtues of the newly available household electrical appliances that, it was claimed, were essential for any modern home and contributed to domestic harmony and happiness.
NZ Electrical Journal, 20 October 1938

The commissioning of Waitaki in 1934 had eased the situation in the South Island, but in the North winter peak loads began to exceed capacity in 1936. By 1937 some supply authorities began to change their tune and fretted that nothing was being done to cope with increasing loads. Popular perceptions also changed; talk was suddenly all about shortages rather than a surplus of electricity. This shift came to a head at the 1938 conference of supply authorities, where alarm was expressed at the situation in the South Island.[7] Rapidly increasing demand had raised maximum load during the winter of 1938 to close to the combined capacity of Lake Coleridge and Waitaki. It also seemed that flows in the Waitaki River might be inadequate to support a planned extension of capacity at the Waitaki station. The supply authorities now warned of an impending shortage of electricity.[8] Semple, however, derided them for being 'panicky', and argued that the recent rapid load growth was simply the satisfaction of a demand that had been suppressed by the Depression, and would soon peter out.

South Island protests, however, hardly had the weight and urgency of those of the North, where maximum load had already exceeded capacity. In the South the incorporation of Southland and the West Coast into the system had artificially inflated the rate of increase in demand over the preceding few years. Kissel argued that it was in fact the southern half of the North Island that was of most concern.

The supply authorities asserted that people were much more aware than they had been ten years earlier of the possible uses of electricity, which they argued had dropped in price by more than a third in real terms over this period. Furthermore, the attractiveness and range of appliances was now far greater than it had been. They complained bitterly that it was they who knew most clearly what was happening, but neither the Minister nor the department would take them seriously. A deputation that met Semple and Kissel in June 1939 was assured — but did not believe — that the existing high growth rate would not be sustained. Indeed loads increased during the winter of 1939, and Semple was now forced to concede the magnitude of the problem. During the previous three years consumption had increased by 50 per cent.

Wartime restrictions

On the outbreak of war, Electricity Emergency Regulations were issued under the Emergency Regulations Act of 1939. These gave Kissel, who was appointed Electricity Controller, extremely wide powers: the 'absolute control of the generation, transmission, distribution, sale and use of electric energy throughout New Zealand'.[9] He was also made the Dominion Lighting Controller, with responsibility for supervising the blackout. There was likely to be a serious shortage of power in the North Island at least, even if wartime industrial development did not greatly increase demand. Virtually no new plant could be installed, because machinery was unavailable. There were also shortages of many items needed for normal maintenance. By 1941 the impact of restrictions was being felt, and from then until 1947 the average annual rate of growth in demand fell to 5.2 per cent.

Actual cuts in supply were avoided for a surprisingly long time. In the middle of 1940, when there was a shortage of coal for the steam stations at Kings Wharf and Evans Bay, regulations were drafted to cut off advertising and display lighting, reduce street lighting and prohibit the use of radiators in the middle and late afternoon. In the event, the Mining Controller was able to allocate coal in the nick of time and the expected crisis did not develop. In February 1941 lighting restrictions were imposed in coastal areas to reduce the risk from enemy action. Street lights were reduced in power and shrouded, advertising signs and floodlights were disconnected and house and shop lights were screened from outside view. More regulations further reduced lighting levels during the year. In early 1941 things again looked bad, but the supply authorities just managed to cope. In March Kissel asked North Island supply authorities to regulate loads, and in May he conducted a radio campaign and extended the half-hour of daylight saving through the winter to stagger the peak and reduce overall demand. Streets were now dimly lit, the electricity available for street lighting having been reduced by 20 per cent for the duration of the war.

Fortunately, hydraulic conditions were exceptionally favourable in 1941–42, although supply authorities were given powers to limit supply and were expected to keep loads within set limits. After a cold spell in May 1942 the situation became critical. All hydro-electric stations and thermal standby stations were fully loaded, if not overloaded, at the peak period between 4 and 6 p.m. In June the government was forced to bring in the Electricity Control Order 1942, which forbade the use of electric radiators and space heaters during peak hours (Sundays excepted) between May and August at businesses, hotels, theatres and other 'places of amusement' in the North Island. This was backed up by another Order, prohibiting the manufacture or sale without permits of radiators and almost all domestic electrical appliances.[10] Both the department and supply authorities put a lot of effort into publicity campaigns in which people were asked to restrict their use of radiators, ranges and lights in order to reduce peak winter loads. In August Lighting Restrictions Orders strengthened the blackout provisions; these also had some effect on the consumption of electricity.

Difficulties in the South Island during the war stemmed from shortages of water rather than of generating capacity. The flow in the Waitaki River during the winter of 1943, for instance, was so low that on average the station operated at less than half capacity, and heavy use was made of any available diesel plant, with private plant in particular being pressed into service. Water in Lake Coleridge had to be used prematurely and the lake was not allowed to build up to its natural level.

In May 1943 a new, extended Electricity Control Order imposed greater restrictions in the North Island on space heating and both indoor and outdoor lighting. When one of Arapuni's generators broke down in June, Semple and D. G. Sullivan, the Minister of Supply and Munitions, were forced to issue a statement to the effect that

> the whole electrical generating system has been working under a severe strain, producing a very much higher level than the system could be expected to carry continuously. An appeal is made to everybody to economise in the consumption of electric power to the utmost extent possible so as to avoid the only alternative, which is the complete stoppage of power in some districts during certain periods of the day.[11]

The installation of the first 20 MW unit at Piripaua that year helped, and the supply of coal was promising, but the Evans Bay plant was mostly out of commission, which led to voltage cuts ('brownouts') over the North Island and brief periods when the power was simply turned off in some areas. A decision to allow supply authorities a 4 per cent increase in their allocations only expanded demand, overloaded stations and led to further restrictions. The Electric Water-Heating Order of July 1943 empowered supply authorities to require homeowners to install thermostats, and laid down that all new or repaired water heaters had to be fitted with thermostats, with supply metered and charged for at an hourly rate. In the North Island existing equipment was to be metered wherever possible. About 40 per cent of electricity consumed was used for water heating in homes and factories and on farms. Almost everywhere in the North Island this had been charged for at a flat rate according to the installed capacity, which meant that there was no monetary incentive to save power. In some areas water-heating hours were also reduced.

In 1944 the second Piripaua unit was commissioned, but problems continued. The metering of all hot-water services in the North Island was made compulsory, and certain non-essential lighting was restricted. There was a good deal of discussion about radio broadcasting, which was eventually cut by 30 minutes during peak periods of electricity demand. By the end of March 1945 some three-quarters of domestic water heaters were metered, enabling cuts in hours to be imposed when necessary. Power shortages became progressively worse, and by 1945 had led to conflict between the Factory Controller and Kissel as Electricity Controller, with the former complaining that critical industries were suffering from a lack of power.

The end of the war in Europe in May 1945 made it even more galling that power restrictions had to continue. The government could not even afford to permit extra lighting for the peace celebrations, the War Cabinet deciding that instead there would be two days during which the wartime restrictions would not apply.

There was no option but to continue with restrictions during the winter of 1945. Matters would have been much worse had there not been control of Lake Taupo (see Chapter Seven), but even so the lake was reduced to unprecedented levels. From the end of May to the middle of July there was hardly a weekday without cuts and disconnections somewhere. The situation was made even worse by the lack of coal for Kings Wharf. Kissel foresaw massive power cuts as the only alternative to a breakdown of the system.

Hydraulic conditions were exceptionally difficult during 1946 and 1947 because of drought conditions throughout the country. Cuts of 20 per cent were imposed in the North Island from March until August 1946, and reimposed in March 1947 for twelve weeks after a temporary lifting of restrictions over the summer had resulted in a surge in demand. In the South Island there were massive 30 per cent cuts from June to August 1947. Kissel underlined the seriousness of the situation in observing that 'the stage has been reached where the load demand has overtaken the Dry-season capacity of the hydro-electric stations'.[12]

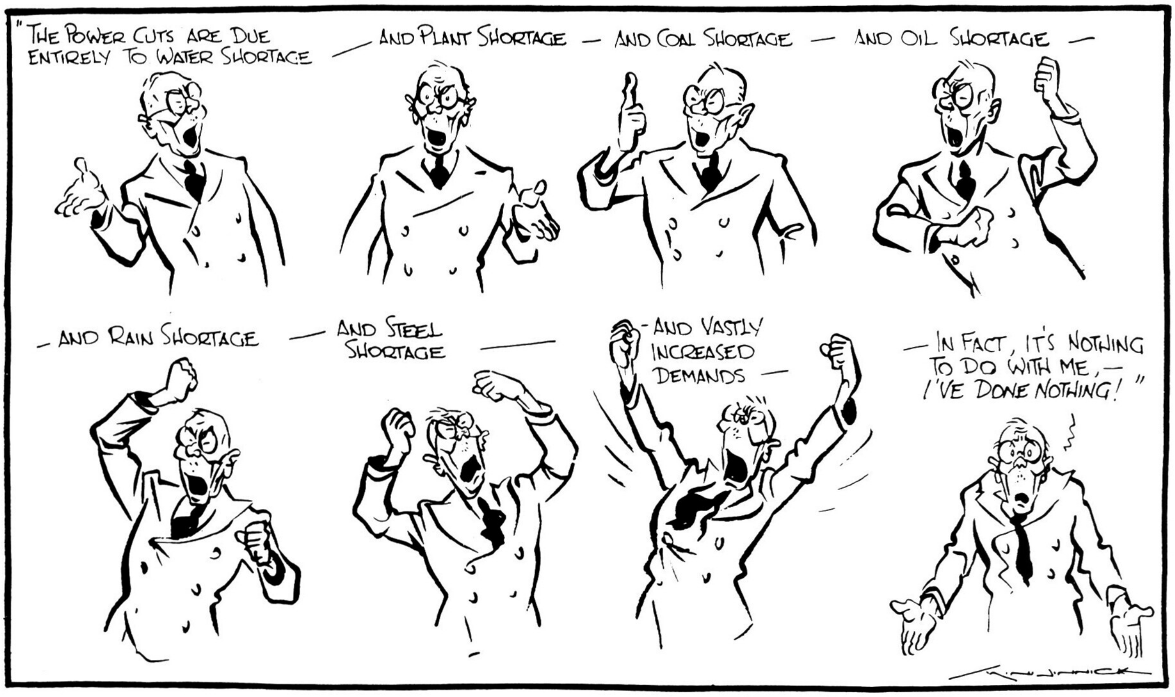
While Lake Karapiro was being filled after the project had finally been completed in early 1947, a cold Easter frustrated the hope that the closing of offices and shops would mean a substantial saving. Wellington streets were blacked out between 7 and 8 p.m., and there were no train services after 10.30 p.m. Cuts of up to 15 per cent were again imposed in the North Island from March to May 1948 after summer allocations were exceeded.

From this time hydraulic conditions eased and supply authorities allowed greater flexibility. In 1949 the wartime regulations were replaced by the Electricity Control Regulations. The position of Electricity Controller was abolished, although the General Manager of the State Hydro-electric Department retained powers of control over electricity supply and use. The tight grip of government was at last relaxed a little.

Electricity takes over

In the early 1940s Kissel anticipated a return to high rates of expansion of demand after the war, particularly as the price advantage of electricity over any rival was so marked that price rises were not likely to have much effect. Kissel estimated that there was likely to be a long-term increase in consumption of 8.5 per cent per annum, an assessment that proved to be remarkably accurate. 1948 marked the beginning of a long-term surge in demand that in fact averaged 8.1 per cent per annum through to the late 1960s. This entailed a doubling of demand every ten years.

Kissel's conclusion was that the department should plan for a 10 per cent annual increase in capacity. This was lower than the previous rate of expansion, and much lower than the supply authorities were arguing for, but still substantial. Nearly 80 per cent of domestic consumers as yet neither cooked nor heated water by electricity, and there was likely to be a housing boom after the war. Officials were talking of building 15,000 houses a year, the great majority of which would be 'all-electric'.


"THE POWER CUTS ARE DUE ENTIRELY TO WATER SHORTAGE —
— AND PLANT SHORTAGE —
— AND COAL SHORTAGE —
— AND OIL SHORTAGE —
— AND RAIN SHORTAGE —
— AND STEEL SHORTAGE —
— AND VASTLY INCREASED DEMANDS —
— IN FACT, IT'S NOTHING TO DO WITH ME, — I'VE DONE NOTHING!"

KILOWATTS AND KILOWHYS

This cartoon shows Bob Semple, Minister of Works and Electricity, blaming absolutely everything except his own government for the chronic power shortages that continued after the war.
Gordon Minhinnick, *NZ Herald*, 17 March 1948

Once wartime restrictions were lifted and the public's confidence in the availability of power was restored, there was an explosion in the use of electricity, particularly for domestic purposes.[13] The proportion of electricity consumed in the home reached a peak in 1955 of just over 60 per cent, having been 40 per cent in 1940. In Great Britain and the United States, domestic consumption was only about one-third and one-quarter of the total respectively.

By the late 1940s electricity had well and truly arrived. Industrial consumption had increased greatly during the war, and by the end of the decade electric motors provided more than 80 per cent of the power used in factories. In only a decade both the number of electric motors used on farms and the domestic demand for lighting, cooking and heating had doubled. Virtually the entire population had now been reached, other than those in remote rural areas, and the use of electric lighting was almost universal, while an increasing proportion of homes had electric ranges. The first data collected on domestic consumption showed that in 1945, 92.7 per cent of households were supplied with electricity, with one-third of households using it for cooking.[14] By 1948–49, domestic consumption amounted to 57.4 per cent of total consumption, with domestic water heating alone comprising 27.1 per cent. Electric motors used in manufacturing and agriculture took another 23.9 per cent, while the commercial sector consumed 10.0 per cent. Water heating used in dairying accounted for 4.9 per cent, while railway and tramway traction, street lighting and other uses together amounted to only 3.8 per cent. A 1952 survey of Lower Hutt state householders showed that all households had a radio and an electric iron, and nearly all had an electric jug.[15] There were vacuum cleaners in three-quarters of the households, electric toasters and electric radiators in about two-thirds, and water heating and electric cookers in about half.

Technological developments and new techniques of mass production in manufacturing were reflected in a continuing decline in the real prices of electrical appliances, whose efficiency and utility were greatly improved. The retail price of electricity, which had fallen steadily from the 1920s, reached its lowest point in the period 1945–50. After that time it rose in nominal terms, but more slowly than did the cost of living, so that its real price continued to decline. It was to remain at a low level up to the 1980s.

General prosperity, improved housing, full employment and rising standards of living after the Korean War and into the 1960s opened the way for the widespread use of a great range of household electrical appliances. Before the war the domestic consumption of electricity had remained confined largely to better-off households. In the pre-war period only electric ranges and radios had been produced locally, but when the wartime restrictions on the purchase of electrical appliances were lifted local firms took up their production with vigour. Electric ranges, electric jugs, toasters, refrigerators, vacuum cleaners, washing machines, radios and electric water heating became increasingly common. In 1940 some 92,000 electric ranges and 107,000 water heaters were in use; by 1965 the numbers had soared to 593,000 and 379,000 respectively.

Domestic consumption was further boosted in the late 1950s and 1960s by the mass adoption of electric radiators and television sets. By 1966, 84.3 per cent of households had electric water heating, 89.3 per cent a vacuum cleaner, 93.3 per cent a radio and 63.3 per cent a television set, while 43.6 per cent used space heaters or radiators as their primary means of heating. New Zealand households had become amongst the most electrified in the world. Electricity continued to eclipse coal gas as a source of energy for cooking, being used by 86.6 per cent of households by 1971. By this time 90.6 per cent of households had a washing machine, 96.4 per cent a refrigerator, 43.2 per cent a deep-freeze, and 26.9 per cent a clothes dryer.

Responding to demand

The government was hard-pressed indeed to meet the country's seemingly insatiable demand for electricity, particularly since hydro-electric projects required a seven- to eight-year lead-time. The first response to the burgeoning demand was the comprehensive development of the Waikato River. Karapiro had been started in 1940, in wartime conditions, and was eventually completed in 1947. Kissel's overall plan for the Waikato had been approved by Cabinet in 1943 and was announced publicly in 1946. In the same year a new government department, the State Hydro-electric Department, was created. It took over from the Public Works Department responsibility for eliminating electricity shortages and satisfying escalating demand at a time when it was very difficult to obtain either material resources or workers to construct any new schemes.

Having overseen this transition, Kissel retired in 1948 and was replaced as General Manager by Arthur Davenport.

Was there any alternative to the development of the Waikato? There probably was not in the long

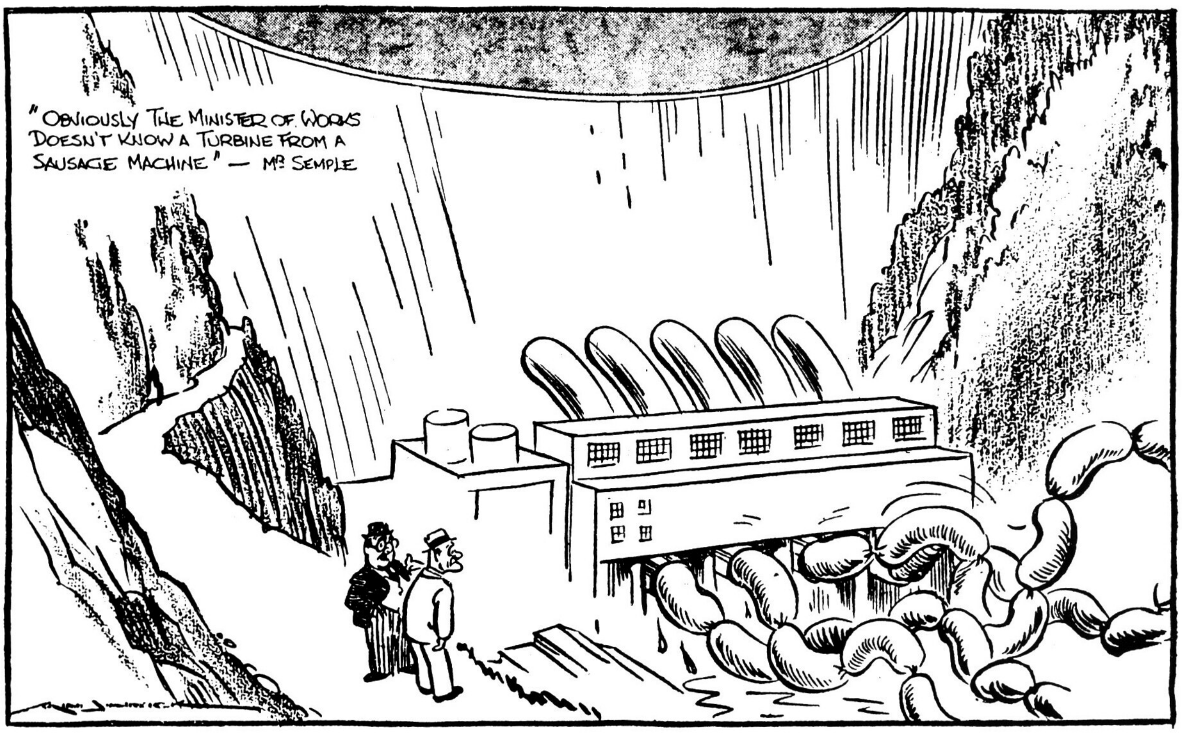
Photograph courtesy of Mr P. Davenport

Arthur Egbert Davenport was born in Marton on 17 April 1901.[16] He joined the Hydro-electric Branch of the Public Works Department in 1923, graduated with a BE from Canterbury University College in 1924, and was involved in power station construction before transferring to Wellington for the period 1927-31. He then became Assistant Electrical Engineer in Christchurch and was Resident Electrical Engineer in Hokitika, Greymouth and Christchurch from late 1936 until 1944. He was then briefly District Electrical Engineer, Auckland, before becoming in 1945 Assistant Chief Electrical Engineer at head office. In 1946 he was appointed Chief Electrical Engineer in the new State Hydro-electric Department, and succeeded Kissel as General Manager in 1948. In 1963 he retired and in the same year was awarded a CMG. He had had to deal with the post-war electricity shortages, the department's reorganisation as the New Zealand Electricity Department and the considerable broadening of its activities into thermal and geothermal generation. He died in Wellington on 15 April 1973.

run, but some people would have expressed this dedication to hydro-electric development less emphatically than did the department and its Minister, or have qualified it by considering a permanent auxiliary role for thermal stations. In the 1940s, and especially after 1943 when it was no longer possible to doubt that severe shortages loomed, there was a great clamour for steam stations, particularly from the supply authorities, simply because of the speed with which these could be installed. Even Semple and Kissel would have installed steam plant if they could have got it, despite their preference for hydro-electricity and doubts about the coal supply. Kissel admitted in 1943 that there would be a case for looking at steam if shortages were to last beyond 1948. He considered that labour was the real problem for the Waikato schemes, and claimed that if he could get at least 3,000 men for the next three to four years he could do without steam.

A report confirmed that steam plant could not be commissioned before 1945 in any case, even if delivery, made hopeless by wartime conditions, was possible. The report suggested that a possible power shortage between the completion of Karapiro and Maraetai could be covered by Swedish steam plant, but Kissel rejected this, believing that there would be no problems once Karapiro was finished. Meanwhile many avenues were explored without success. Purchase of a variety of new and second-hand plant from various countries was considered. Even floating portable oil-fired plants and the use of obsolete battleships or cruisers were looked at, but there was nothing for it but to put up with shortages and restrictions until the hydro-electric stations were commissioned.

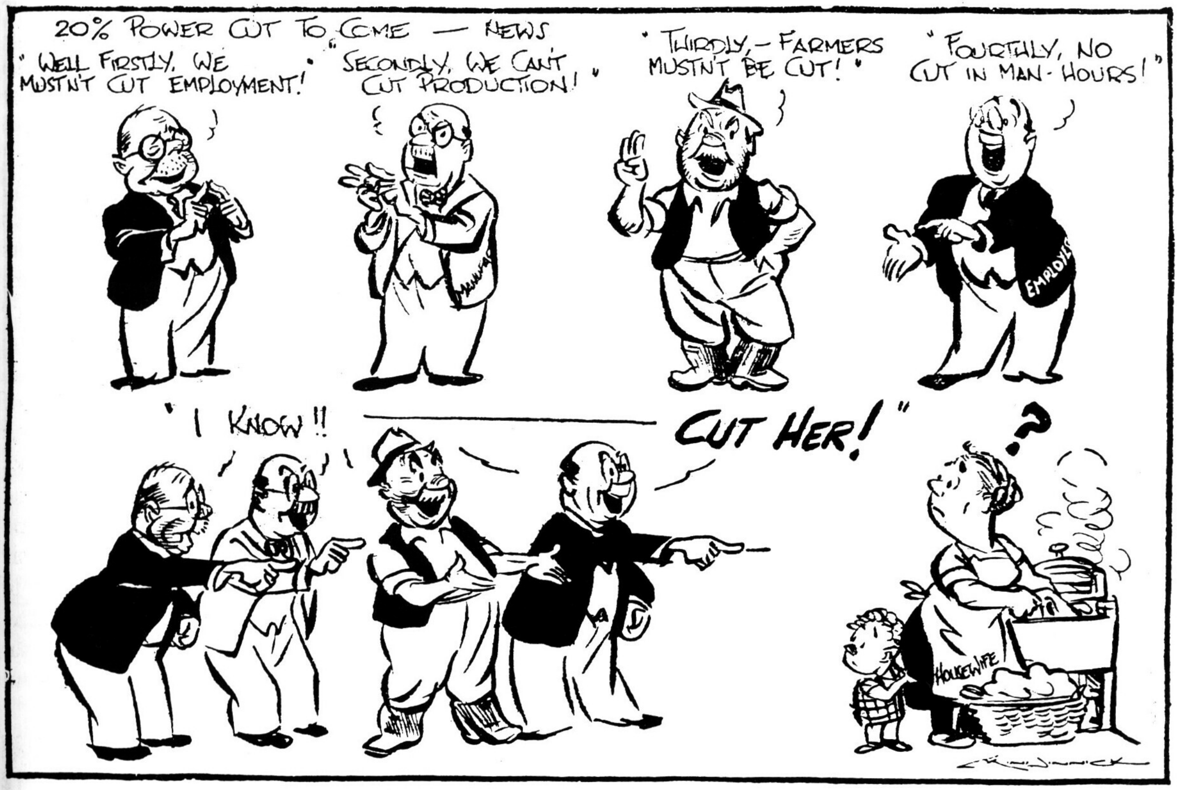
After Labour lost the election at the end of 1949, National's W. S. (Stan) Goosman, a former roading contractor, became Minister of Works and took charge of the State Hydro-electric Department. This did not result in any dramatic change in policy other than a shift in emphasis towards private enterprise. Indeed the backlog of projects and shortages left him little choice. Goosman accepted Kissel's assumption that demand would grow at 10 per cent per annum


"OBVIOUSLY THE MINISTER OF WORKS DOESN'T KNOW A TURBINE FROM A SAUSAGE MACHINE" — MR SEMPLE

"Increased Production, O.K. — But how am I going to *explain* it to the Oppo. Boys?"

Semple had some harsh words for his successor in the National government, W. S. (Stan) Goosman. This cartoon, which depicts Maraetai I disgorging sausages instead of water, implies that Goosman had a lot to learn. He was, however, to remain in charge of both Works and Electricity until 1963, apart from three years in Opposition.

Gordon Minhinnick, *NZ Herald*, 16 November 1951


20% POWER CUT TO COME — NEWS
"WELL FIRSTLY, WE MUSTN'T CUT EMPLOYMENT!"
"SECONDLY, WE CAN'T CUT PRODUCTION!"
"THIRDLY, — FARMERS MUSTN'T BE CUT!"
"FOURTHLY, NO CUT IN MAN-HOURS!"
EMPLOYERS
"I KNOW!! — CUT HER!"
?
HOUSEWIFE

EASY!

Restrictions in electricity consumption hit domestic consumers hardest, which was understandable when domestic consumption was rising towards a peak of more than 60 per cent of total consumption in 1955. Gordon Minhinnick, *NZ Herald*, 14 April 1952

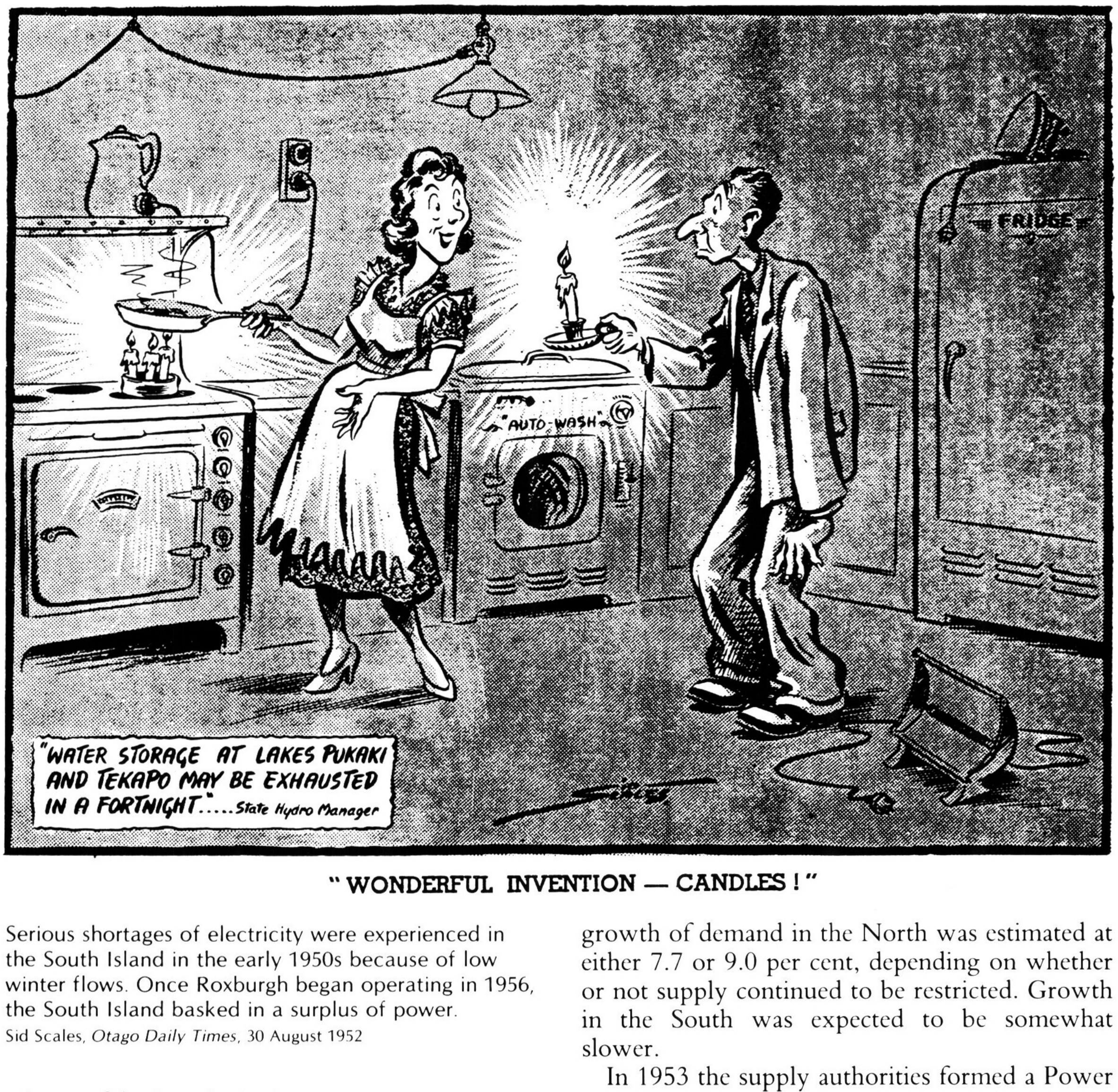
over the next decade, and continued the development of the Waikato River. He was more of an advocate of steam plants than Semple, but recognised that their running costs were much higher even if their capital costs were lower, and agreed that the best course was to add hydro-electric plants while investigating geothermal possibilities. Goosman differed from Semple in his willingness to consider the use of overseas contractors and work-forces for both design and construction in order to accelerate the programme. This was reflected in Atiamuri, designed by a British firm, and much of the construction of Roxburgh, undertaken by a British-Swiss consortium.

In the immediate post-war years shortages of labour and materials conspired to prevent the completion of the construction programme. No sooner was one hydro-electric station commissioned than spiralling demand leap-frogged over the increased capacity, and restrictions on consumption had to be continued. Annual increases in consumption during the 1950s were as high as 12 to 13 per cent.

In the early 1950s there was much activity on the Waikato. Maraetai was begun in 1946 and completed in 1953, while Whakamaru was constructed between 1949 and 1956. The corresponding solution to the South Island's less acute shortages was the massive Roxburgh station on the Clutha River, which was approved in 1947 and built between 1949 and 1956. Other work at this time included lake control works at Pukaki and Tekapo and the Tekapo A power station, further work at Waikaremoana and major extensions at Waitaki and Cobb River.

The planning system

The development of more systematic planning was a consequence of severe problems of supply that arose in 1953–54, and of increasing concern over the continually growing demand in the North Island. Previously, the supply authorities had instigated several planning exercises to supplement internal departmental projections.[17] In 1943 northern, central and southern subcom-


"WATER STORAGE AT LAKES PUKAKI AND TEKAPO MAY BE EXHAUSTED IN A FORTNIGHT."....State Hydro Manager
AUTO-WASH
FRIDGE

"WONDERFUL INVENTION — CANDLES!"

Serious shortages of electricity were experienced in the South Island in the early 1950s because of low winter flows. Once Roxburgh began operating in 1956, the South Island basked in a surplus of power.
Sid Scales, *Otago Daily Times*, 30 August 1952

mittees of the Supply Authorities Association each reported on their need for power for the next ten years. The northern report, which was the most developed, suggested that as an absolute minimum a 5 per cent annual increase in demand should be allowed for while the war continued, and that this would probably rise to 15 per cent in the immediate post-war years, with a slightly slower rate of increase expected up to 1953. In order to meet the considerable shortfall anticipated, the report recommended the installation of a substantial steam plant (up to 60 MW) in addition to pressing on with longer-term hydro-electric development. Further separate reports on the North and South Islands in 1948 contained estimates of demand up to 1955. The annual growth of demand in the North was estimated at either 7.7 or 9.0 per cent, depending on whether or not supply continued to be restricted. Growth in the South was expected to be somewhat slower.

In 1953 the supply authorities formed a Power and Finance Utilisation Committee to estimate future demand, with three representatives from and the active support of the State Hydro-electric Department, after Davenport asked them to prepare estimates for the next five years. This committee reported the following year that there would be an overall annual increase of 9.8 per cent until 1958, with the rate of growth in the North Island being significantly higher than that in the South.

There was little reason to doubt the projections of demand, Goosman having reiterated in 1953 that, at least until 1963, planning should be on the basis of a 10 per cent annual increase in the North Island. This would involve completing the Waikato stations and building on the Kaituna and the

Rangitaiki, as well as installing steam capacity. Even this programme would produce only a 7.5 per cent annual increase after 1955, with the possibility of significant shortages in a dry year.

In September 1953 Cabinet decided that Atiamuri should go ahead, but that Waipapa, Ohakuri and Braeburn (soon to be dropped) in the South Island — all originally proposed a year earlier — should not be undertaken until at least 1955, and then only after a review of the whole power programme. Waipapa was in fact approved later in 1953, but construction was delayed until 1955 and the project was not completed until 1961. Other Waikato projects followed in quick succession, although approval for each scheme remained uncertain until shortly before work started. As a result of this activity, government spending on station construction as a proportion of total public works expenditure increased from 16 per cent in 1950 to 25 per cent by the end of the decade, when work on the Waikato reached a peak.[18]

Atiamuri was constructed between 1953 and 1958, Ohakuri was approved in 1955 and finished in 1961, and Aratiatia was approved in 1959 and completed in 1964. This brought to an end the development of the North Island's major river. Serious consideration had meanwhile been given to developing geothermal resources at Wairakei for power. The Wairakei scheme was approved in 1953, and construction began in 1956.

In the year ending March 1954 an exceptionally large increase in consumption of 12.6 per cent precipitated some consternation amongst power planners. The North Island figure was more than 15 per cent, in part because of a switch to electricity by industry in the wake of the 1951 waterfront strike.[19] North Island power restrictions had been suspended from April 1953, but in the South unfavourable hydraulic conditions meant that supply authorities had to reduce consumption by 20 per cent from late July until October 1953. During the winter of 1953 load exceeded capacity on several occasions. Restrictions were lifted for 1954 after a good year hydraulically, but during that winter peak load again began to exceed capacity. Problems with the construction of Roxburgh at this time compounded the difficulties.

In 1955 both the government and the supply authorities initiated planning reports, the two committees combining to produce the 'First Report of the Combined Committee on the North Island Electric Power Supply'.[20] This initiated a system of annual planning reports that continued until the recent abandonment by the government of such documents. The combined committee comprised Davenport as chairman, M. G. Latta, his Chief Engineer from the State Hydro-electric Department, two representatives from the Ministry of Works and five from supply authorities.

This report presaged a flurry of developments that changed the shape of electricity generation in New Zealand. A new set of problems had to be considered now that virtually all the Waikato was earmarked. Ending restrictions in the North Island was the government's major priority, but there were no more cheap and easily exploitable hydro-electric resources available. Davenport missed few opportunities to remind Goosman of his 1950 pledge to eliminate shortages. Alongside the continued exploitation of the remaining hydro-electric resources, new thermal sources of power rapidly took centre stage, and the linkage of the North and South Islands was put firmly on the agenda.

The 1955 Combined Report pointed out trenchantly that the existing programme would meet only 65 per cent of the estimated unrestricted demand projected to 1962–63. Uncommitted hydro-electric options were limited, with only Aratiatia and the Kaituna River having been investigated. These projects would not be easy to develop with existing resources, and power from them would be relatively expensive. The committee's overall conclusion was that 'in the North Island further large hydro-electric stations are not so readily available as in the past and the time has come to introduce other types of power stations to operate as base load plants in conjunction with the hydro-electric system'.[21]

The committee recommended that a 120 MW coal-fired station be built immediately at Mercer (the Meremere station) with provision for extension, that another 40 MW be obtained from Wairakei in addition to the 40 MW already approved, and that a 60 MW gas-turbine plant (the 'Korokoro' station) on the Petone foreshore be investigated as quickly as possible. These projects were to take precedence over Aratiatia and Kaituna. The State Hydro-electric Department was to become the New Zealand Electricity Department in 1958 in recognition of the increasing role of alternative forms of generation.

Within the committee, F. M. H. Hanson, the Commissioner of Works, was the only person to ask whether continuing to meet unrestricted demand was a realistic aim. He became concerned by the expenditure involved and questioned the priority given to increased electricity generation when much of this was consumed domestically rather than assisting the creation of wealth by industry.

Hanson argued that unless the rate of growth was capped the country would become locked into a cycle of recurrent shortages and desperate efforts to catch up. New Zealand could not have everything it wanted. More resources devoted to power generation meant less for everything else that was important, from schools and hospitals to irrigation, roads and bridges. It was not just a question of money. The fashion was to blame part of the looming power crisis on Treasury: all would have been well but for its insistence a few years earlier on delaying the start of new works. Hanson argued that, whatever Treasury's attitude, a shortage of manpower and physical resources would have prevented the original programme being carried out, and that it was essential to find a way to curb the growth of demand. But such arguments did not suit the temper of the times and had to await the oil crises of the 1970s and increased public awareness of the importance of conservation of natural resources before they were heeded.

The basic problem was that domestic power was so cheap that there was no economic incentive to be efficient or use less. Hanson suggested the possibility of a radical change in the price structure, perhaps by a regressive tariff with a quota and heavy penal rates. New Zealand could even start working seriously towards the co-ordination of all types of energy, particularly gas and electricity. This had been talked about at length, but little had been done. However, both the government and the supply authorities accepted the committee's recommendations and Latta, who had in 1950 produced a crucial paper arguing for a cable across Cook Strait, was sent overseas to investigate gas turbines and steam plants, as well as developments in undersea transmission cables.

Meremere, with its planned capacity increased to 180 MW, was approved in 1955 and built in the period 1956–58. By late 1955 investigations had also started on the next major hydro-electric project in the North Island — the Tongariro development. In a significant departure from existing policy, these investigations were to be carried out by consultants. At the same time the proposal to construct the massive Benmore station on the Waitaki River and to link the two islands by an undersea cable across Cook Strait was announced.

In a speech to the supply authorities' annual conference in 1955, Davenport had stressed the need for integrated national planning.[22] A combination of the commissioning of Whakamaru and an extremely wet winter in 1956 eased the North Island situation and allowed demand to be met. However, low rainfall in the following winter required a 10 per cent reduction in consumption by supply authorities, although actual power cuts were avoided.

A second planning report produced in 1957 concerned the entire country. The new Combined Committee on the New Zealand Electric Power Supply, which had been appointed in July 1956, acknowledged that Roxburgh, which began generating that year, would cope with the South Island demand until 1965. The problem was largely in the North. It recommended the approval in principle of a Cook Strait cable and that Benmore be approved as soon as possible. The upper Waitaki rather than the Clutha was favoured for longer-term South Island needs because it was closer to the load centre. The committee stated that the Huka Falls should not be disturbed. It also suggested that there should be a hydro-electric station on the Kaituna, or its equivalent elsewhere if the river was not suitable, in spite of observing that the cost of developing the Kaituna was likely to be too high. (This was to become Matahina on the Rangitaiki River.) It recommended that Wairakei should be extended to a second and a third stage, and that Aratiatia should be approved and provision made for an extra unit for both Atiamuri and Ohakuri.

The committee also repeated the previous recommendation of a Korokoro gas-turbine plant (enlarged to 107.5 MW), which was intended as a peak-load complement to Wairakei and for stand by and the firming of hydro-electric supply in dry years. The Ministry of Works preferred peak load to be provided by a hydro-electric station but bowed to the majority of the electrical engineers on the committee. (The ministry had never been happy with the idea of a gas-turbine plant.) The argument for the gas turbine was fairly strong. There would be a substantial saving in transmission costs, since the station would be near its load, and it could be used as synchronous condensers for voltage control, particularly if there was a cable across Cook Strait. There was considerable local opposition, however, including from Labour MPs such as Walter Nash and Michael Moohan. Labour MPs also tended to attack the Cook Strait cable, most apparently thinking that geothermal power would be the salvation of the North Island. Benmore was approved in 1957 (initially with only two units to supply the South Island), and construction started the following year and was finished in 1965. The Cook Strait cable was finally to be approved in 1961, after considerable controversy and delay, and laid in 1964.

The second Labour government

In late 1957 Labour became the government and Hugh Watt Minister of both Works and Electricity. Watt's natural orientation was towards the Ministry of Works, and he did not develop the kind of relationship that Goosman had had with Davenport. By 1958 New Zealand's economic situation had deteriorated sharply. Export prices had fallen rapidly, imports were rising and overseas reserves were at an extremely low level. Watt was preparing a White Paper that was to prove a crucial intervention. In April both the Electricity Department and the Ministry of Works were asked to review electricity needs with a view to reducing capital expenditure. This request followed a year in which a record post-war increase in consumption of 13.6 per cent had been recorded. Drought conditions over the summer had resulted in the imposition from mid-February of a 15 per cent reduction in supply, which was maintained into the winter of 1958. North Island lake storage fell to dangerously low levels in July. The commissioning of the first unit at Meremere in August did allow the restriction to be reduced to 10 per cent, but the underlying problem of a lack of capacity remained.

The Electricity Department's review failed to acknowledge the political reality that Korokoro was doomed, and restated the combined committee's basic trinity: the Cook Strait cable, Benmore and Korokoro. Davenport was cautious about Aratiatia, arguing that no early decision could be taken because the public had yet to be persuaded that the beauty of the rapids need not be lost.

The view of the Ministry of Works was that Korokoro should give way to more generating capacity on the Waikato, perhaps at Maraetai. There should also be a greater commitment to geothermal development, delay of the Cook Strait cable for two or three years, and more emphasis on new North Island hydro-electric schemes. The need for Benmore was accepted, but from the standpoint of averting a South Island shortage after 1965 rather than for its association with the cable. Aratiatia should be pushed forward, and for peak demand extra machines could be installed at Ohakuri and Atiamuri.

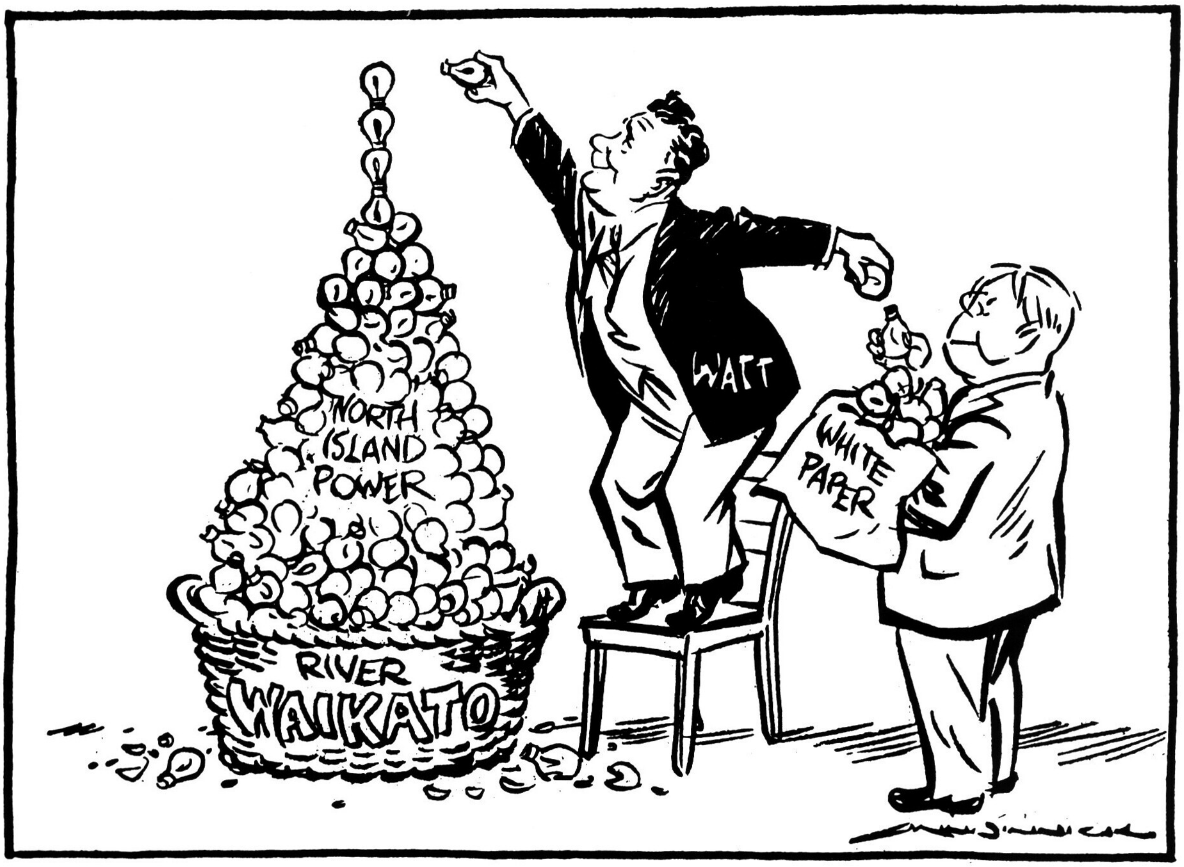
Watt now made it clear to the Electricity Department that he wanted alternatives to Korokoro. There was no possibility that the Minister of Finance, currently working on his 'Black Budget', would sanction the considerable expenditure of overseas funds for both plant and fuel that would be required for Korokoro.

Watt's 1958 White Paper was approved by Cabinet in August and published without any serious consultation with the Electricity Department, to whom it came as a bombshell. Watt called a meeting of the Supply Authorities Association, but simply read out a summary of the conclusions already reached and refused to allow the department to give technical information to the association's engineers.

The White Paper made decisions radically divergent from the recommendations of the 1957 combined committee.[23] Taking the Ministry of Works line, it argued for the greater use of hydroelectric resources in the North Island and for geothermal development. The Korokoro gas-turbine proposal was abandoned and replaced by a proposal for a second station at Maraetai (Maraetai II) for peak loads. The plans for additional units for Atiamuri and Ohakuri were retained — they were to be installed by June 1961 — and Aratiatia was to be advanced by six months. The elderly Kings Wharf and Evans Bay plants were to be kept going. Such plans for the North Island would, it was argued, allow the deferral for a year of the Cook Strait project, to which Labour had been opposed when in opposition. Watt also placed considerable emphasis on the potential of the Rangitaiki River and the Tongariro development, which it was asserted could produce up to 750 MW, as much as all of the Waikato stations.

The White Paper also followed Hanson in casting doubt on the assumption that the government should necessarily continue to respond to spiralling domestic demand and spend ever-increasing amounts of money on power stations, especially when these required considerable overseas funds.

Senior officers of the Electricity Department, and probably supply authority engineers also, believed that the White Paper's proposals were crude, misleading, expensive and far inferior to the previous programme. They depended on unrealistic expectations of what could be got from



A BASKET OF EGGS

Hugh Watt puts all his 'eggs' into the Waikato River hydro-electric basket. His White Paper on electricity development of August 1958, which ran counter to the views of both the Electricity Department and the electrical supply authorities, caused considerable controversy. The department favoured a gas-turbine station and the rapid approval of the Cook Strait cable.

Gordon Minhinnick, *NZ Herald*, 26 August 1958

Meremere and Wairakei; and Maraetai II could not replace Korokoro. As both Davenport and Goosman became fond of saying, Maraetai II would not produce a single extra unit of energy over time, because its use of headpond storage would leave the combined Maraetai stations short of water later on. They also argued that the White Paper was too optimistic about North Island hydro-electric resources. While at least one further large scheme (Tongariro) was possible, it would not be operational for more than a decade, and others proposed were technically or economically unattractive by comparison with those in the South Island.

Watt was determined to have control. The combined committee was reorganised as the Planning Committee on Electric Power Development (henceforth, Power Planning Committee) with Watt in the chair, two members from the Electricity Department, two from the Ministry of Works and one from Treasury. Supply authority representation was dropped.

A subsidiary committee was set up to advise the planning committee as to future power needs, with the Electricity Department's General Manager in the chair and representatives from the Electricity Department, supply authorities and Treasury together with the Government Statistician. The supply authorities were thus effectively sidelined.

Meanwhile North Island power restrictions were finally lifted by Christmas 1958, following the commissioning of Meremere and Atiamuri. The Kings Wharf and Evans Bay stations were largely shut down.

The Power Planning Committee met again in 1959 but did little more than recommend Matahina in preference to the long-mooted Kaituna scheme. Approval for Matahina was quickly given, construction began the following year and it was finished in 1967 after some delay. In 1960, notwithstanding an increase in consumption of 12 per cent the previous year, the Power Planning Committee had to sit on its hands and await the resolution of the Manapouri negotiations, investigations of the Cook Strait cable, and the results of the pilot hot-water plant at Wairakei. Investigations of the Wanganui and Tongariro still continued, so nothing could be proposed for those possibilities either.

After the re-election of National at the end of 1960, the Power Planning Committee was reorganised more along its original lines, with Davenport as chairman and two other members from the Electricity Department, two from the Ministry of Works, three from supply authorities and one from Treasury. The reconstituted committee quickly (by March 1961) produced a report that marked a shift back to pre-1958 thinking. None of the new North Island hydro-electric possibilities that had been advocated by the Ministry of Works — the Kaituna, Mohaka, Rangitaiki and Wanganui — were now seen as very promising. It was strongly recommended that the Cook Strait cable project should be begun, as should Aviemore, together with a scheme on the Rangitaiki (subject to Ministry of Works reports). The Cook Strait cable was approved in the same month. Investigations were to continue on both the Waitaki and Wanganui Rivers. Aviemore got the go-ahead in 1962 and was finished by 1968, while the expensive Rangitaiki scheme was dropped in 1963. The additional four units needed to bring Benmore up to its full capacity were ordered in 1961. But prospects for the Wanganui receded; it was far from clear that the river could be dammed, because this would affect many farmers.

In September the committee issued a second report, which was influenced by the need to keep capital expenditure down and conserve overseas funds. The committee in effect recommended the termination of Maraetai II, and the government rapidly acted on this. Maraetai II was mothballed in order to cut capital expenditure. At the same time Matahina was delayed two years to 1967.

Rethinking generation

As the demand for electricity continued to spiral upwards, a range of thermal projects based on sophisticated new technology and using coal, gas and oil were examined from the early 1960s onwards. The discovery of Kapuni gas in 1959 added another dimension to power planning and ultimately, after much indecision, resulted in approval of the Otahuhu gas-turbine station in 1966 and its construction over the following four years. The old Kings Wharf and Evans Bay steam plants were now partially dismantled.[24] Another factor contributing to a new approach was the emergence of steeper peaks in demand. The commissioning of base-load plants such as Wairakei and Meremere now made more peak-load capacity necessary. Gas-turbine stations were well suited to this purpose.

The early 1960s saw other important changes. In 1963 Davenport retired and E. B. Mackenzie became General Manager. Goosman retired from politics at the 1963 election, and T. P. (Tom) Shand became Minister of Electricity when the Holyoake government was returned to office.

The first sign of the change of emphasis came in 1963, when an unexpectedly high increase in consumption of 12.7 per cent caused the Power Planning Committee to look beyond hydroelectricity for the additional capacity which was needed by 1968. The department's attitude was also changing thanks to the government's emphasis on the provision of electricity for industrial development, such as a steel industry, and because future hydro-electric projects looked like being increasingly expensive. The committee proposed 120 MW of gas-turbine plant fuelled by Kapuni natural gas, subject to the cost being acceptable. But making the decision to use gas for generating electricity was to take a number of years.

The committee also recommended in 1963 that all potential hydro-electric sources for the next fifteen to twenty years should be investigated. Tongariro should go ahead, with the Tokaanu station completed by April 1971, and Stage 3 of Wairakei should be completed by the same time. Two stations on the upper Waitaki should also be approved in principle. In the same year a renegotiated agreement with Comalco resulted in the government assuming responsibility for the construction of the Manapouri scheme and allowed it access to a considerable block of surplus Manapouri power. Manapouri was built in the period 1964–69.

In 1964 the Power Planning Committee reflected on long-term trends. Capacity had doubled in the nine years since 1955, yet shortages still threatened as consumption was increasing even more rapidly than before. The

Eric Bruce Mackenzie was born in Pomahaka, South Otago, in 1907.[25] He studied for a BE at Canterbury University College, completing his practical work at Horahora and Arapuni. He joined the Hydro-electric Branch of the Public Works Department in 1931, and worked in Hamilton as an engineer's assistant, in 1936 becoming an Assistant Electrical Engineer, supervising extensions to transmission lines. He was transferred in 1940 to the Cobb River project to take charge of electrical installation and transmission lines, and became Nelson's Resident Engineer until 1946. He moved to head office as Design Engineer in 1947 after the branch became the State Hydro-electric Department. Mackenzie was appointed Assistant Chief Electrical Engineer in 1952, Assistant General Manager in 1961 and General Manager in 1963. In 1972 he chaired an executive meeting of the World Energy Conference at Wairakei. He retired that year and was awarded the CBE, having been closely involved as General Manager in the Manapouri negotiations and Commission of Enquiry, the purchase of natural gas for electricity generation, and the construction of the New Plymouth power station. He died in October 1983.

domestic half of the increase was attributed to a massive switch to the use of electricity for space heating after supply restrictions were lifted, and also to the advent of television. If extra power were needed, how was it to be obtained, given that expansion at Wairakei was no longer viable and no decision on the use of Kapuni gas had been made? By now it had been realised that Wairakei could not sustain continued development, and the Stage 3 proposal was struck out. Delays were also being experienced on the Manapouri project.

The answer was to advance the Tongariro scheme, speed up Aviemore and, now that New Zealand had an oil refinery, build a 240 MW oil-fired station at Marsden Point. Another 150 MW of gas-turbine capacity was also added. The first three stages of the Tongariro scheme were approved in 1964, and construction soon began. Marsden A was approved the following year and was built remarkably quickly, by 1967. The surge in demand also caused the planners to recommend that a seventh 30 MW unit be added to Meremere, and that overseas consultants report on the viability of a station using Buller coal. This culminated in the approval of a thermal station at New Plymouth in 1968, and its construction over the following six years.

Maraetai II was resurrected to provide the extra peak capacity needed in association with these projects, and to capitalise on the extra energy that would be available from water diverted into the Waikato by the Tongariro development. The proposal to finish constructing Maraetai II had an easy passage, so clear did it seem that the country's generating capacity should again be doubled in a decade. Another new element introduced at this time was the possibility of nuclear power, which the committee stated 'must be introduced in New Zealand by about 1977'.[26] Canadian plant was seen as the most promising. It was recommended that sites should be investigated, and in 1965 the Kaipara Harbour was examined. A site on the Motu River was also briefly considered for a hydro-electric scheme. In this year the shift in emphasis to thermal generation strengthened further as the peak-load Waipapa II station, proposed in 1964, was abandoned, as was any development of the Motu River.

The power planning report of 1966 was shaped by the new Manapouri agreement, which allowed the Crown considerably more power until the early 1970s, and the recommendation of a 600 MW coal-fired station at New Plymouth. As a result the Upper Waitaki development was deferred for several years. The comparative economics of hydro-electric and thermal generation were discussed carefully, reflecting the change in thinking that was occurring. The committee argued that if indigenous fuel was used thermal generation would have an edge because of its lower capital costs, but that the heavy drain on overseas funds imposed by importing fuel would tip the balance in favour of hydro-electricity. The committee continued to emphasise the latter's long-term benefits, but had to recommend the introduction of thermal plant because of the limits of available capital and labour and the lack of final investigations of hydro-electric resources.

An unexpected fall in the growth of demand in the late 1960s — the rate of increase in consumption suddenly dropped to only 2.5 per cent in the year ending March 1968 (against the estimate of 8.4 per cent) — caused some heart-searching amongst the power planners. Had the long awaited 'saturation' of demand finally come to pass? The Power Planning Committee noted that 'the low percentage increase . . . is without parallel in the long history of electricity supply in New Zealand'.[27] It was put down to mild weather, retail tariff increases and a serious economic recession. The Upper Waitaki development was approved at last in 1968, and constructed over a period stretching from 1969 to 1985.

Continued recession flattened the demand curve for some time. Growth was 5.0 per cent in the year ending March 1969, and 6.1 per cent and 6.0 per cent for the following two years. In retrospect it can be seen that the recession of the late 1960s marked the onset of a new phase, with a lower annual rate of growth which averaged only 6.4 per cent over a decade.

However, the 1969 Power Planning Committee did not change its approach significantly. It was still asserted that there was no sign of the saturation point being reached, although the feeling was expressed that 'sales cannot possibly maintain their normal historical rate'.[28] Increases in demand were still projected at 7 to 8 per cent per annum, and indeed the estimates were increased to allow for the taking of power by New Zealand Steel and by Comalco for its aluminium smelter.

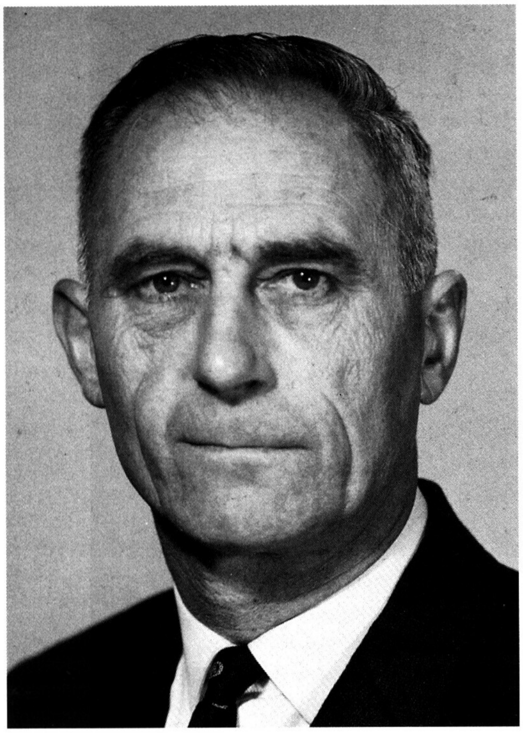
Gas, which had disappeared from view in 1967, reappeared as a source of fuel for the New Plymouth station with the discovery of the Maui field in 1969. The large quantities of gas available led the 1970 Power Planning Committee to re-introduce the possibility of other gas-fired thermal plants. This developed into the Auckland Thermal No. 1 and No. 2 proposals, which were eventually dropped from the plan in the late 1970s.[29] However, a slower-than-expected economic recovery and the late commissioning of New Zealand Steel caused estimates of future demand to be revised downwards slightly that year.

Demand bounced back to a high level in the following two years, with a 10.9 per cent and then a massive 13.6 per cent increase. But these were misleading years, which were more of a rebound from the recession than a return to the pattern of earlier times. The new demand from Comalco's aluminium smelter and considerable growth in industrial demand during 1972 were also factors, as was a cold winter. In that year the planners still expected the annual increase in demand to return to 8 or 9 per cent, but in fact the average rate of increase dropped to about 5 per cent in the mid-1970s. Marsden B made its first appearance in the power plan in 1972 as a base-load oil-fired station. It was to be built between 1976 and 1979, but was never used because of the oil crisis and is still mothballed. In 1972 P. W. Blakeley took over as General Manager of the Electricity Department.

Labour regained office at the end of 1972. By 1973 planners were having serious doubts about whether growth would be sustained at previous levels, in spite of that year's high rate. By the 1960s industrial consumption was rising as a share of the total, and in the early 1970s exceeded domestic consumption for the first time since the beginnings of the state system. The New Zealand Steel plant at Glenbrook opened in 1970, and the Tiwai Point smelter began taking power in 1971. The electrically intensive pulp and paper industry was now an important user. The Kinleith mill had opened in 1953, the Tasman and Caxton mills at Kawerau from 1955, and the Whirinaki mill began operating in 1973. From this time onwards domestic demand grew much more slowly, with only space heating increasing rapidly, while industrial demand rose markedly.

The energy crisis

1973 proved to be an extremely difficult year which brought into question the traditional planning parameters of unrestricted supply, 'average' weather conditions and 'normal' economic circumstances. The early months of 1973 were very dry, and depleted water storage saw a return to the restrictions that had plagued the post-war years. Electricity allocations had to be reduced by 5 per cent from July to September, cuts were made in water heating and there were several weekend blackouts. In December the situation was made worse by the oil crisis. Thermal generation using oil was strongly discouraged and limited by financial restrictions. Another dry summer resulted in further restrictions of 5 per cent from mid-February to the end of July 1974. For all these reasons consumption grew by only 5 per cent in the year to March 1974.



Philip William Blakeley was born in Lower Hutt on 3 April 1915.[30] He received his training at Wanganui Technical College and by correspondence from the British Institute of Engineering Technology. His notable career began in 1931, when he became an apprentice electrician for the Wanganui-Rangitikei Electric Power Board. He joined the Hydro-electric Branch of the Public Works Department in 1939 as a leading hand at Tuai, before becoming an electrical fitter, Assistant Engineer at Waitaki, head office and Nelson, and in 1949 Resident Engineer at Mangakino. From 1953 he worked in head office and then was District Electrical Engineer at Hamilton in 1959–61 and Assistant Chief Engineer at head office in 1961–63 before becoming Chief Engineer. In 1968 he was made Assistant General Manager and upon Mackenzie's retirement in 1972 became General Manager of the Electricity Department. He retired in 1979 and was awarded a CBE in 1980.

The construction programme was advanced as a result of these problems, and the Power Planning Committee pushed for sufficient capacity to cover dry seasons. The massive coal-fired station at Huntly was approved in 1973, in order to cover shortfalls expected to develop in the late 1970s, and was constructed over the following decade. Agreement on the use of Maui gas had been reached in early 1973, and it was now designated for New Plymouth, Huntly and the two gas-fired thermal stations proposed for Auckland. The Labour government also asked for an additional 600 GWh per annum to be allowed for an as-yet-unspecified industrial demand with a high load factor. It was in this context that the Rangipo part of the Tongariro development and the two packaged gas-turbine plants at Stratford and Whirinaki were approved, and that Ohaaki was first included in the power plan, along with other new projects (such as a possible nuclear-powered station). Both Stratford and Whirinaki were started in 1975, with the former being rapidly completed by the following year and the latter coming into operation in 1978.

Planning became increasingly difficult because of the need to balance contingencies such as the availability of gas, oil and coal, and to take account of recently introduced environmental-assessment procedures and public concern over such issues. The year to March 1975 saw virtually no growth in consumption, which was attributed to the restrictions of the previous two years and to two warm winters, as well as to the country's increasing economic difficulties and the effect of the oil crisis. The forecast long-term growth rate from 1979 was adjusted substantially downwards to 6.6 per cent per annum, but considerable debate about the five years to 1979 resulted in a more pessimistic minority view being expressed by the representatives of the Treasury, the Department of Statistics and the Ministry of Energy Resources.

From 1975 the government became less keen on using gas for electricity and began to explore other possible uses. This process eventually culminated in the early 1980s in the construction of the so-called 'Think Big' projects: the ammonia-urea, methanol and synthetic petrol plants in

Taranaki converting natural gas into a variety of products. In the year to March 1976 domestic growth rebounded considerably after restrictions were lifted and because of a cold winter, but industrial growth was below expectations. The overall rise in consumption was 9.4 per cent.

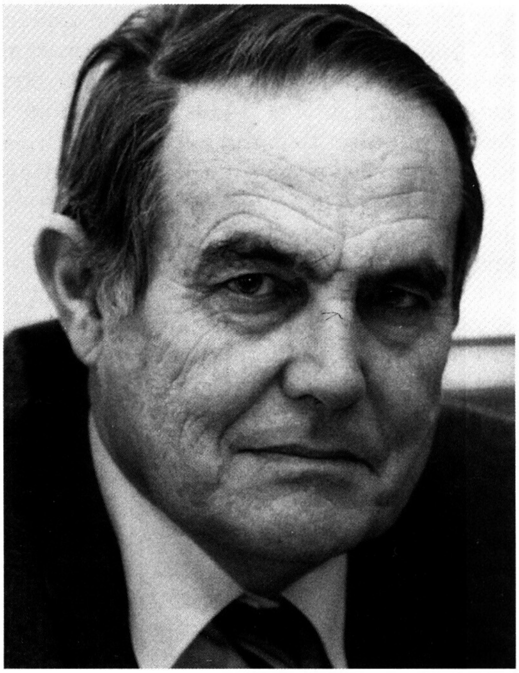
In 1976 the incoming National government changed the parameters of planning. Restrictions on government spending resulted in the deferral of a number of projects, and the government substantially increased the bulk-supply tariff, which had not changed since 1967. The annual growth rate of consumption fell to 4.2 per cent, and would have been even lower had not the Tiwai Point smelter taken up a lot of power.

Energy conservation was also now firmly on the agenda, and from 1976 this was taken into account in making forward estimates. The restrictions of 1973–74 had flowed into conservation campaigns in 1975–77, and the Electricity Amendment Act No. 1 1976 made it a goal of the department to reduce the growth of demand by promoting measures to achieve greater economy and efficiency in electricity usage. People now became more energy-conscious, and interested in home insulation and off-peak storage heating.

Again the planners differed on the extent to which demand was tapering off, but it was generally recognised that the days of considerable increases were over. As a result, the projections were again lowered and the planned gas-fired Auckland thermal stations were deferred. Any possibility of a nuclear power station disappeared from the plan. In 1978 both Auckland thermal stations were dropped and almost all projects other than Ohaaki and Clyde were deferred beyond the fifteen-year planning period.

The end of an era

This decision marked the end of the constant search for new stations that had driven planning since the war years. Work was now largely concentrated on the completion of projects under construction, which included the Tongariro, Upper Waitaki and Huntly projects, and on those already well down the planning track, notably Ohaaki and Clyde. Scheme F for the Clutha River, including the Clyde dam project, had been approved back in 1976, but the Clyde dam itself did not get the go-ahead until 1981 and the station is still to be commissioned. Approval for the last project, Ohaaki, was given in 1982 and it was commissioned in 1989.



Kevin Daniel McCool was born in Palmerston North on 12 September 1922.[31] After studying at Victoria University College for an Arts degree, and serving in the army and air force during the war, he attended the Canterbury School of Engineering and graduated in 1949 with a BE (Electrical). He joined the Electricity Department in 1950, and his early experience was of the construction of the Haywards substation. In 1952 he transferred to the Protection Section, head office, where he was closely involved in the emerging use of computers for the protection of the transmission system. In 1965 he joined the Systems Operation Branch, where he was promoted to Principal System Control Engineer in 1970. In 1976 he became Chief Engineer (Development), and in 1977 represented the department at the Royal Commission enquiring into nuclear power. In 1978 he was appointed Assistant General Manager, and in 1979 he became General Manager of the Electricity Division of the Ministry of Energy. McCool completed his service as General Manager in 1987 when the Electricity Division became the Electricity Corporation of New Zealand, having overseen the period of planning for major energy projects in the early 1980s and, from 1984, the division's reorientation towards corporate accountability, restructuring and exposure to market forces.

After 1978 growth in demand fell to low levels, and in the year ending March 1980 the unprecedented happened — there was actually a marginal decline in consumption of 0.4 per cent. Some growth returned in the 1980s in conditions of sustained recession, but the rate of growth was much lower; the average from 1977 onwards was only 2.9 per cent per annum. With an expected surplus of generating capacity, the National government decided in 1980 to look at encouraging electricity-intensive industries, such as a second aluminium smelter, the expansion of New Zealand Steel's operations, and pulp and paper mills. Power planning was rejuvenated for an anticipated additional demand of up to 5,000 GWh per year. By this time the Electricity Department had become the Electricity Division of the newly formed Ministry of Energy, and K. D. McCool had replaced Blakeley as General Manager.

The first Energy Plan, of 1980, which combined the previous Power Planning Committee and Forecasting Committee reports, suggested that considerable additional capacity would be required from 1985. It allowed for the potential increase in demand by advancing the commissioning dates of the Upper Clutha projects, and recommending the conversion of the mothballed Marsden B to coal, and the introduction of the Ngawha geothermal scheme in Northland and a second large thermal station in the Waikato. In 1981 the projected demand from electricity-intensive industry increased considerably to about 8,000 GWh, and the Lower Waitaki proposal was introduced into the plan. It was also decided to refurbish the Meremere station. In the 1982 Energy Plan the possibility of development of the Lower Clutha was introduced if South Island hydro-electric development was favoured by government. Subsequently there was also interest in the Motu River, a coal-fired thermal station near Mokau or in the King Country, the Mokai geothermal field near Taupo and, in the South Island, lignite as a potential fuel.

The last Energy Plan was published in 1985, and after a less thorough Energy Issues Paper in 1986 the publication of public planning documents of the kind produced since the mid-1950s came to an end. None of the new possibilities mooted in the Energy Plans of the 1980s has been acted upon, apart from the refurbishment of Meremere. The recent completion of Ohaaki and virtual completion of Clyde brought to an end the post-war era of the continual construction of new power stations.

CHAPTER SEVEN

The Waikato

THE GOVERNMENT'S major response to the wartime and immediate post-war shortages was the co-ordinated and comprehensive development of the hydro-electric resources of the Waikato River.

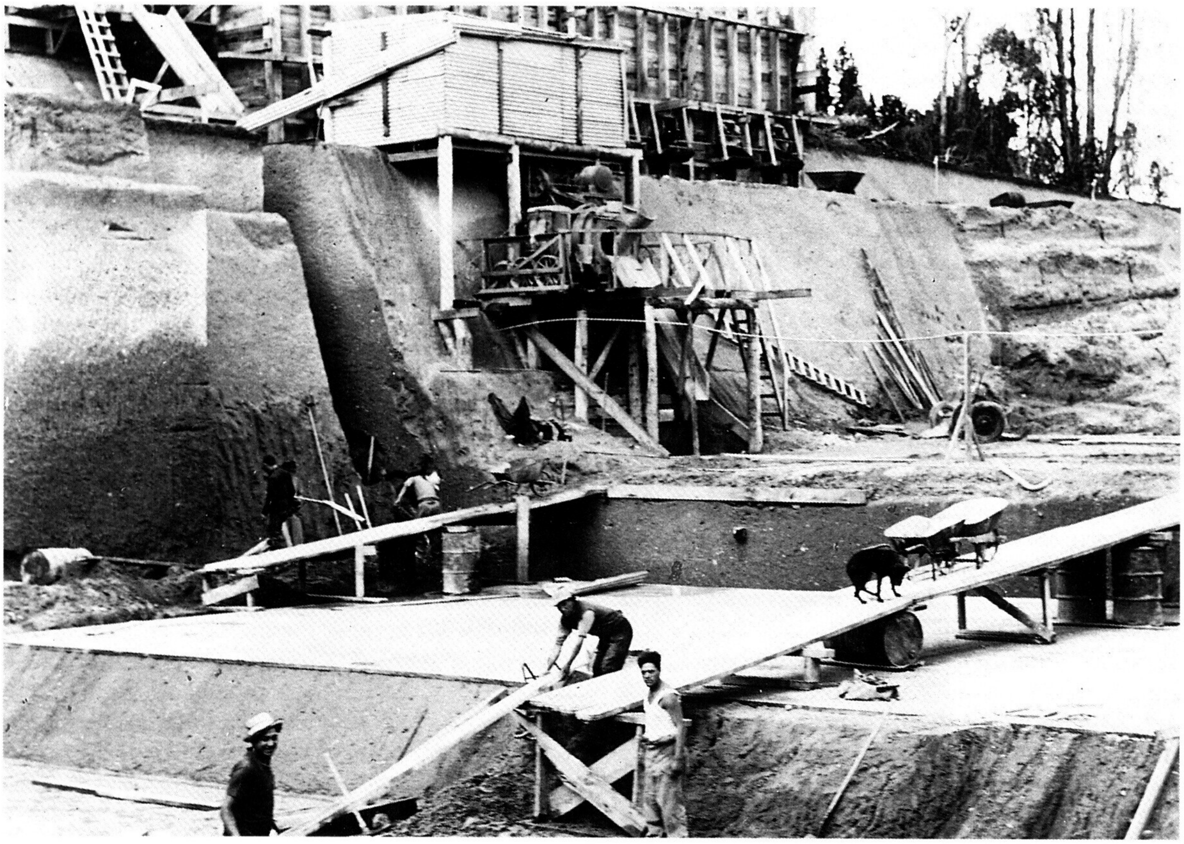
From Taupo to Cambridge there was a fall of some 1,100 feet, much of it in gorges, of which very little was used by the existing Horahora and Arapuni stations. At the Taupo outlet the average flow is some 4,700 cusecs, midway down the river at Whakamaru it is 6,400 cusecs, and at Karapiro, the last in the chain of stations, it is 8,100 cusecs. Kissel was convinced that sooner or later the entire river should be developed. It had the highest flow in the North Island, and the most stable flow of any of New Zealand's major rivers because of the broad seasonal distribution of rainfall and the large storage capacity of Lake Taupo. After earlier surveys in 1916–17 the department had begun to investigate the Waikato again by 1932, when a geologist looked at the river between Lake Taupo and Cambridge and, amongst other things, pointed out the potential of the narrow rocky gorges at Whakamaru, Maraetai and Waipapa, sites that had not been noted in the reports of 1904.[1] In May 1933, comprehensive surveys of the river from Arapuni up to Lake Taupo were begun. The survey team was provided with tents, a boat, an outboard motor and, subsequently, a Model A Ford tourer. Apart from staple provisions the surveyors had to live off the land. In the Mangakino area a local was employed as guide and packman. They worked their way laboriously upriver for almost a year, crossing the narrowest point of the Whakamaru Gorge on a slab of timber that had been thrown across. In 1934 the same team surveyed downstream from Arapuni as far as Cambridge.

One story has it that a small survey party was to carry out preliminary work on the Karapiro site. A survey hand drinking in a nearby pub got into conversation with a reporter, who then released a 'scoop' that the government was going to build a dam at Karapiro. This caused great consternation and embarrassment in Wellington, from the Minister downwards, since Karapiro had not been officially recognised and the Minister knew nothing about it.[2]

From 1935 onwards the department began to draw up plans for the development of the Waikato. These were suspended in the years 1936–37 because of the extensions to Arapuni, and finalised in 1939. Kissel for a time considered the possibility of a tunnel about ten miles long, running north from the Western Bay of Lake Taupo, and a pipeline down to near the confluence of the Mangakino Stream with the Waikato River, but this was abandoned because of active faulting in the rock of the area.

In June 1939 Kissel put to the Minister a scheme of development known as the 'ten-year plan'. Given the state of investigations, it could not be very precise. Control of the level of Lake Taupo was a crucial element, since the interconnected North Island system lacked storage capacity and Waikato River flows were higher in spring and summer when load was low.[3] (The lake today provides about 15 per cent of the country's hydro-electric storage.) Storage at Lake Taupo would also at last allow Mangahao to be run in the optimum way, using its stored water as quickly as possible and then awaiting the next flood for refilling.

The work on controlling Lake Taupo was carried out in 1940–41, and involved excavating a diversion channel for the river about half a mile



Preparing foundations for the Lake Taupo control works, some twenty feet below the riverbed, *c.* 1940. A combined bridge (for the main highway) and control-gate structure was built across the river.
Alexander Turnbull Library

from its outlet from the lake, deepening the river and building across the river a control-gate structure which was combined with a bridge for the main highway north. The lake was controlled over a range of five feet (that is, within its natural range of fluctuation).

Karapiro

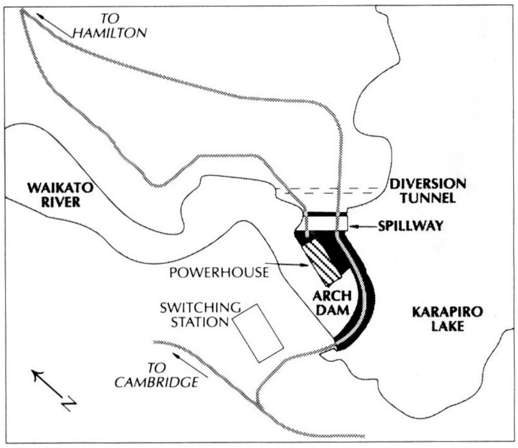
Karapiro, close to Cambridge and known locally as the 'Crows Nest', was favoured as the first major development after Arapuni, because it seemed the best option for producing cheap power quickly. However, work proceeded slowly because both men and resources were hard to find. Taking contours and levels was arduous, and the sinking of shafts and drives was backbreaking work. Drilling was done with antiquated equipment. Subsurface investigation by drives, shafts and bores did not begin until September 1938, and it was another year before it became clear that a dam could be built there, after extensive boring showed that considerable grouting would be required for the foundations. Tens of thousands of tons of concrete would have to be injected to control water seepage. Most of the Waikato dams were to be fraught with technical difficulties because the faulted, jointed volcanic rock caused leakage and instability. Complex grouting techniques were developed as a result.[4]

Investigations were completed in 1939. Kissel suggested that a start should be made on Karapiro before the end of the year. He also mentioned possible schemes for Whakamaru, Maraetai and Ohakuri, probably in that order. Meanwhile other sites selected for development were investigated further.

At this point the possibility of a steam station at Huntly was raised in Cabinet. Kissel's response was well rehearsed. He pointed out that there was little difference in the capital cost, while the expense of fuel and operating staff and the requirements for overseas funds would be much greater for a steam plant, and coal supplies were not necessarily guaranteed. In February 1940 Cabinet approved the building of Karapiro. Kissel proposed optimistically that the station should be built in three years. This was perhaps a tactic to press for more men and materials. Huge Kaplan turbines were to be used.

After more test boring and the erection of a works camp, the construction of Karapiro began in mid-1940 with the diversion tunnel. This was the first major hydro-electric project for which heavy machinery was used extensively. Semple had stated in 1936 that 'in an age when machinery is doing so much to relieve the burden of hard work, and to reduce expenditure in every direction, I could not agree to continue to carry out work by [such] methods [as a system of unemployment relief]'.[5] The bulldozer was reckoned to do in three days what would take 100 men a whole week. There were trucks that could carry twelve cubic yards of material, and 'mechanical navvies' to fill them. In 1936 a new agreement struck with the New Zealand Workers' Union, covering all Public Works wage-earners, introduced a 40-hour week, improved living conditions, increased wages and extended holidays and leave. By 1940 Semple could boast that the department had 4,336 machines — many of them diesel-powered — including 295 tractors, 171 graders, 73 excavators and drag-lines, 147 compressors and 52 locomotives.

Karapiro: Constructed 1940–47. Head 100 feet. A concrete arch dam, 1,089 feet long and 219 feet high, with gravity abutments taking the thrust, incorporates the spillway and intake structures. The powerhouse forms part of the dam structure. Three welded steel penstocks, 21 feet in diameter, lead to three Kaplan turbines — the largest of that type when installed — with automatically controlled variable-pitch blades, which drive 30 MW generators. Total capacity is 90 MW.



By October 1940 foundation work had started with the removal by bulldozer of the soft pumice sand overlying solid rock. By November the initial twin tunnels for the very large (26 feet high and 950 feet long) horseshoe-shaped diversion tunnel had almost been driven through and work on the sluice gates was well under way. By now there were 230 men employed, living in a well-established camp consisting of wooden huts rather than the corrugated-iron ones of Arapuni. However, many of the single men's huts had canvas tops. The camp had a YMCA building with facilities such as a post office, reading room and library, billiards and 'ping-pong' rooms, and a canteen. There were dances held almost every week, and 'motion pictures' were shown. Church services were held fortnightly. However, gambling seemed to be the major form of recreation, especially for the single men. The YMCA tried its hardest, but because its social programme did not emanate from the workers themselves it was not wholly accepted. In 1944 some of the men discussed the need to organise leisure time in another way.

From the start work suffered badly from labour shortages resulting from conscription. The project was one of the first major public works for which Maori formed a substantial proportion of the work-force. Many Maori were drawn in as a result of the Industrial Manpower Regulations of 1942. (The Waikato projects continued to attract Maori, who in 1947 made up 19 per cent of the work-force, and in 1950, 23 per cent.) Some workers were there unwillingly, and many who began work were requisitioned for urgent defence construction and other more essential tasks. The population fluctuated considerably. As a result the diversion tunnel, then the largest of its type constructed in the country, took two years to complete.

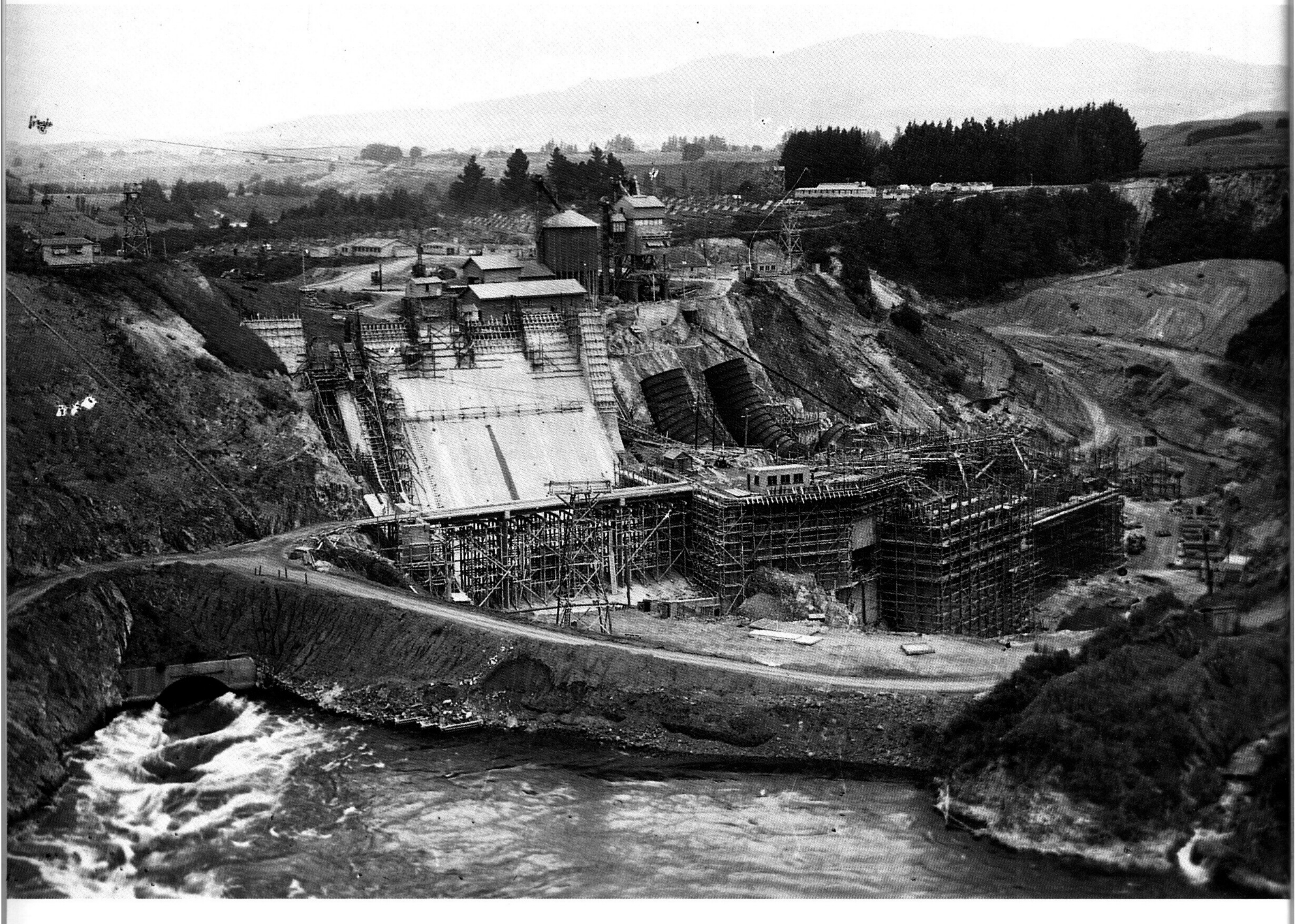
The project had less than half the manpower it needed for most of the war. Work was suspended in 1942 because of crippling shortages of men and plant, and remained virtually at a standstill in 1943, apart from the completion of the diversion tunnel. The 200 men at Karapiro early in 1943 were little more than a quarter of the number necessary. The shortages of labour extended to design and draughting staff. Nevertheless, in mid-1943 Semple — unrealistically — decreed that Karapiro was to be completed by May 1945.

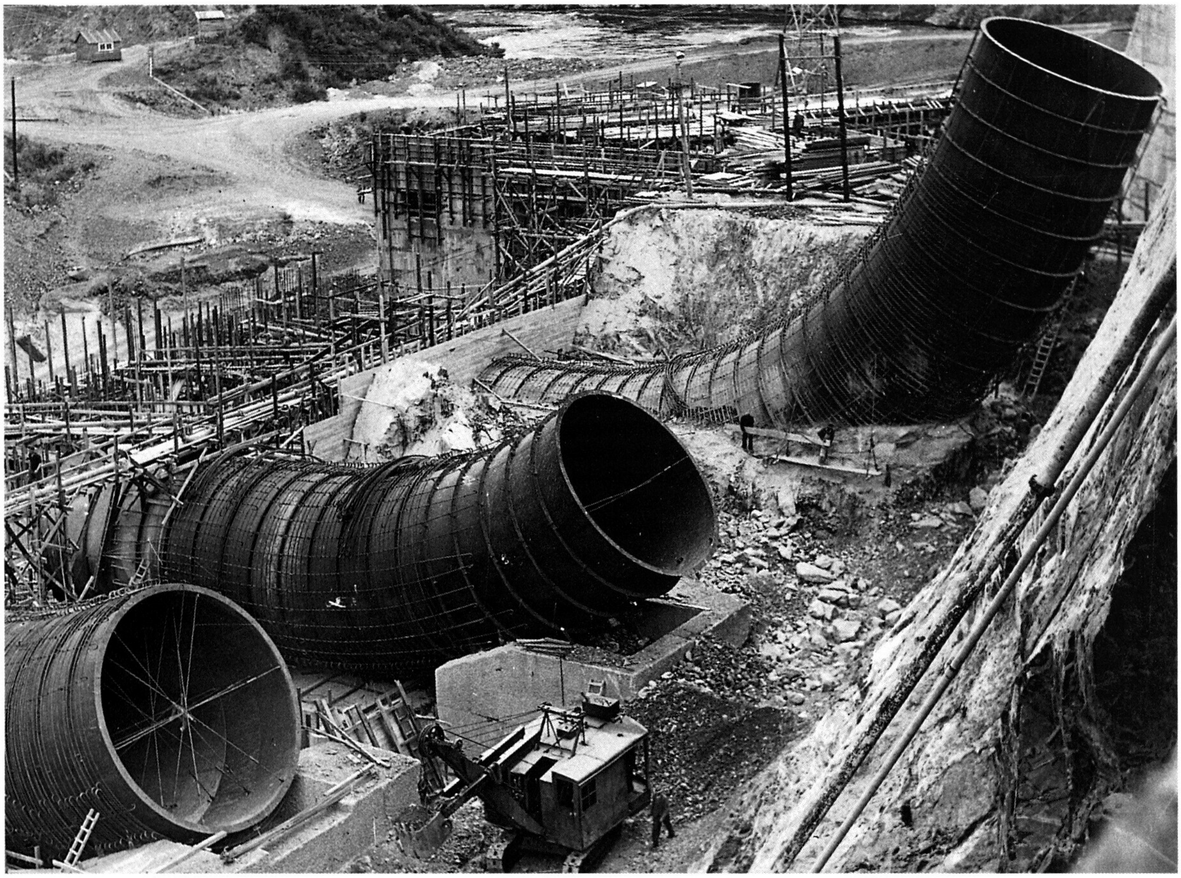
The river was diverted on 12 September 1943, and soon afterwards the diversion tunnel created a spectacular sight as a 'great cataract' formed when the Waikato River in flood rose above the level of the tunnel entrance and plunged back into the riverbed at the exit. The tunnel and one recently completed coffer dam withstood the flood, but the other coffer dam was partly submerged. The work-force increased to 700 in 1944, but this was still insufficient. That year excavations for the arch dam, its gravity abutments and the powerhouse were well in hand. Concreting for the dam had begun and the steel penstocks were being fabricated.

By early 1945 excavations were complete, the powerhouse was being built and the dam was going up rapidly. An approach was made to the manpower authorities and numbers rose to 1,000, but carpenters were still scarce. It was claimed that a third of the men directed to Karapiro were totally unfit for the work, apparently because of their lack of experience as part of a disciplined work-force. There were social problems such as drunkenness and fighting, and the Resident Engineer complained that the behaviour was well below normal departmental standards.

In April Semple announced that hydro-electric development had superseded housing in priority and now came second only to urgent defence construction, of which there remained very little. There was intense pressure to complete the project as quickly as possible because of the continuing shortages of electricity. The work-force reached a peak of 1,136 in 1946 as the dam reached its crest height and the powerhouse was completed.

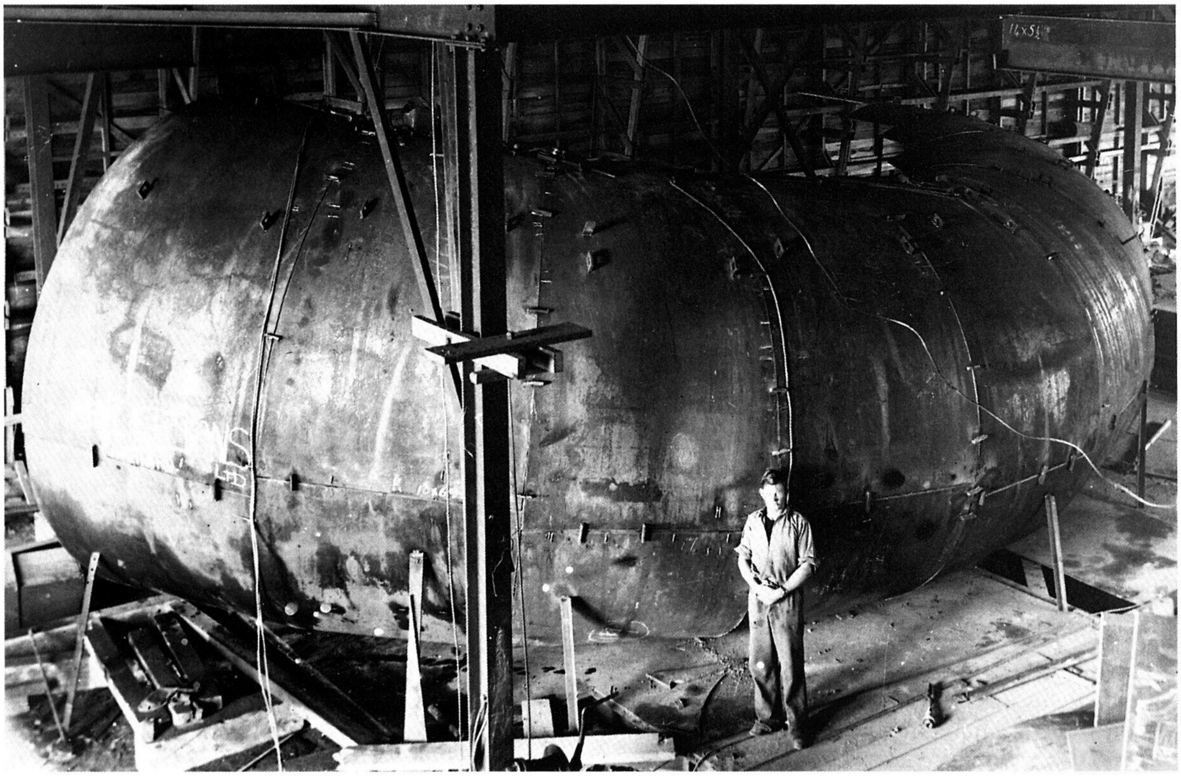
After the Waikato River was diverted (note the diversion tunnel outlet at bottom left), construction of the gravity abutment, spillway and powerhouse at Karapiro began in 1945. Two steel penstocks rise from the partially complete powerhouse. The dry riverbed is on the right, and the public works camp on the far side of the river can be seen behind the construction site.

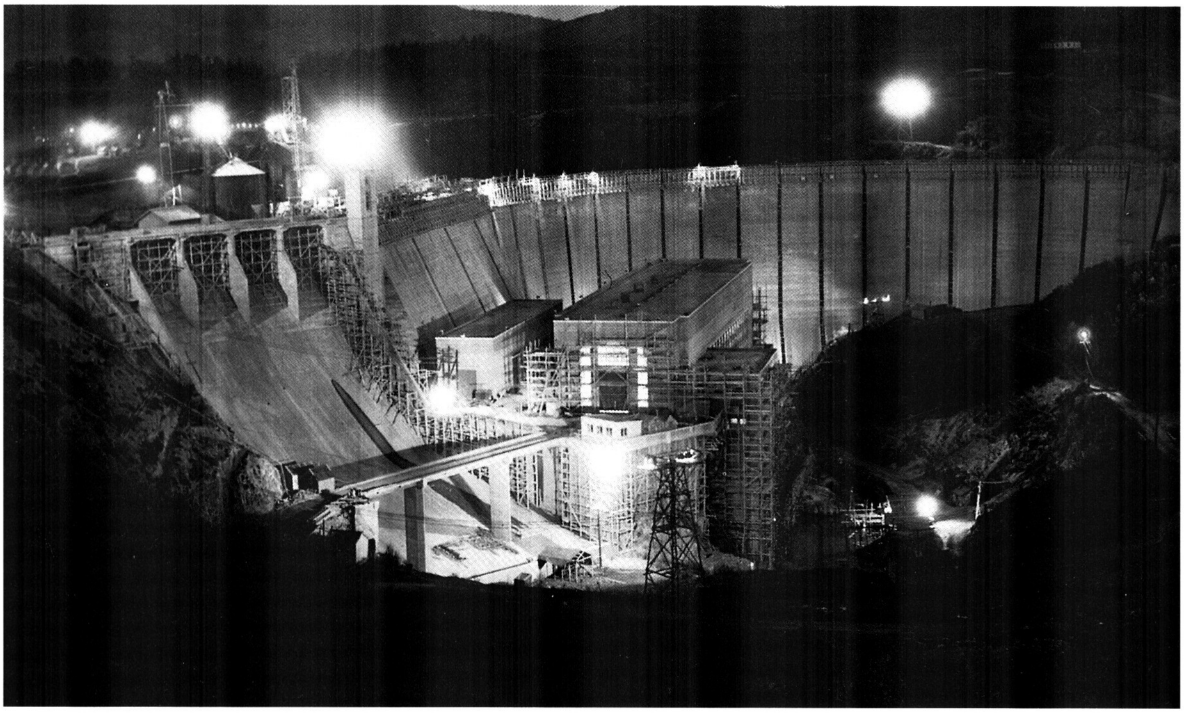




Above: The large welded-steel penstocks, which were 21 feet in diameter, were a feature of the construction of Karapiro.

Below: Here a scroll case for one of Karapiro's very large Kaplan turbines is being welded together in Anderson's workshop.





Construction proceeds by night as well as by day at Karapiro, *c.* 1946, as the powerhouse is completed and the arch section of the dam is finished.

Karapiro was at last finished at last in 1947. In April, after carrying the entire river for more than three years, the diversion tunnel was partly closed by a concrete gate so that only half the river's flow continued downstream. This lowered the river level at Hamilton by ten feet. The lake was filled, inundating Horahora, part of the state highway, a bridge across the river and the site of the Public Works camp. Some 25,000 people came to watch the water rising.

It was symptomatic of the power shortages that Horahora was kept running until the last possible moment. Nearly all the main plant was left behind to be covered by the new lake. As the *New Zealand Herald* reported:

> The greater part of the Horahora power house . . . was flooded today [6 April] while men who had not slept for two and a-half days worked against time to salvage thousands of pounds worth of hydro-electric equipment. Thirty-nine hours after the gate was lowered into the diversion tunnel at Karapiro the quietly rising lake waters backed up the tailrace and entered the building . . . Rising at about a foot an hour, the water welled up through the generators and by midnight they were almost submerged. Crowds of visitors lined the banks of the headrace this morning to watch the station drown. Inside the 35-year-old concrete power house a last-minute drama was taking place . . . engineers and salvage gangs waded back and forth bringing out valuable switchgear, steel girders and floor plating . . . two generators, still revolving, whipped the scum-covered water to a froth . . . . Even after the water had almost covered them, the two generators on the lower floor continued to turn . . . They pounded the water all day.[6]

As Horahora disappeared from view a group of Maori women sang a song of farewell and a member of the station staff played 'The Last Post' on his cornet.

The first of the three 30 MW units, the largest installed thus far in New Zealand, went into service in May, the second in September and the third in May 1948. The new lake became renowned for aquatic sports such as rowing, water-skiing, power-boating and yachting.

Kissel had continued to work on his scheme for the development of the Waikato during the war, and in August 1943 it was adopted by Cabinet. The 'ten-year plan' became the basis for the vast North Island expansion of the post-war years. Kissel argued the case for large-scale hydro-electric development against the many supply authorities that favoured steam or small hydro-electric plants.[7]

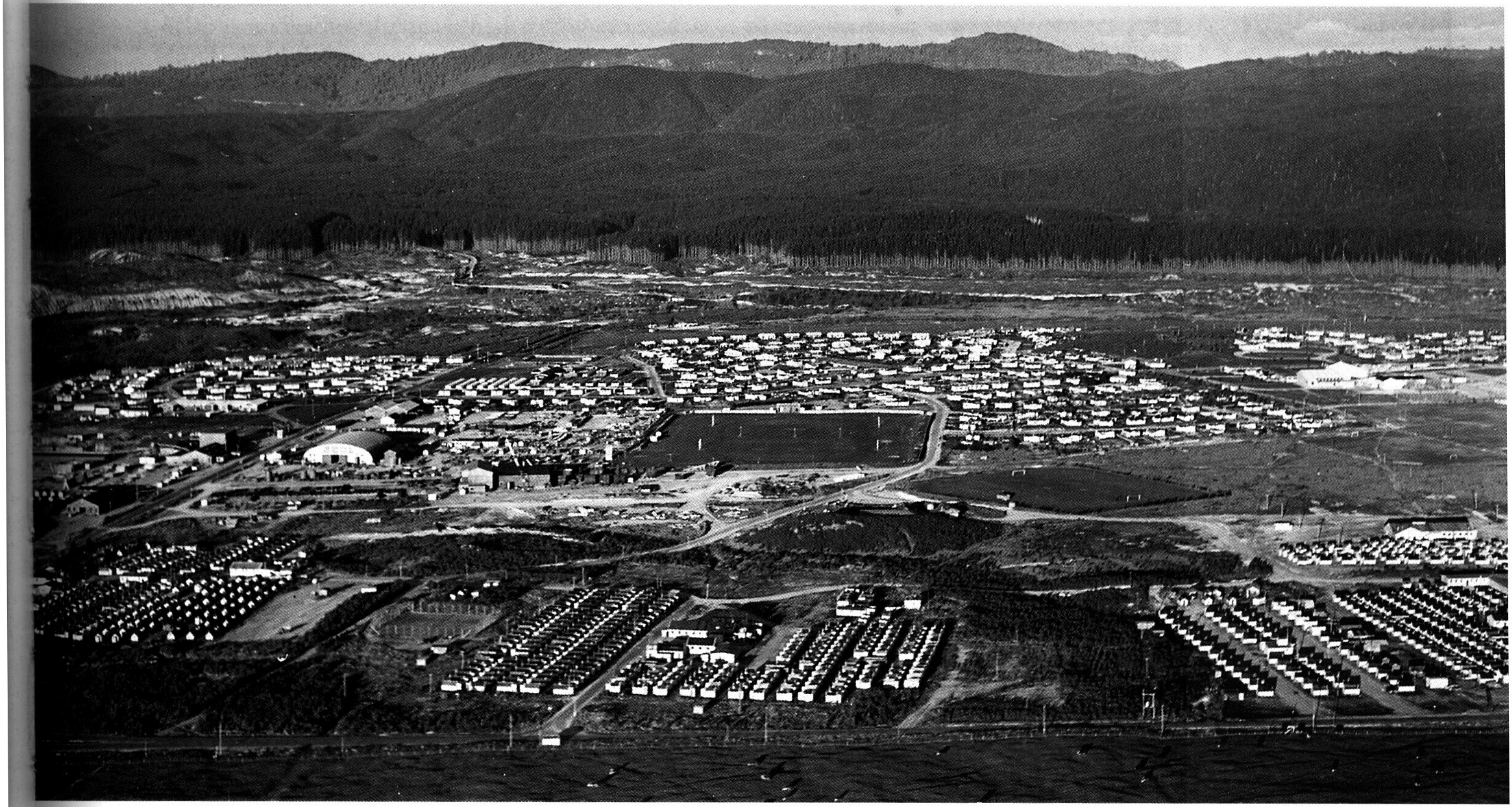
The additional capacity needed was to be provided by a chain of stations on the Waikato that would use virtually all of the head between Taupo and Cambridge. Sites at Whakamaru and Ohakuri had already been proved, though some boring was still required, and it seemed certain that a dam could also be built at Maraetai. Whichever project was decided upon should be started well before Karapiro was finished.

Mangakino

The new town of Mangakino, fourteen miles from Tokoroa, was to be the centre for the construction of the Waikato stations that were far from any existing settlements.[8] Semple boasted that Mangakino would be a model town.

He proposed to 'erect a semi-permanent town . . . By providing better accommodation and some of the amenities of town life we shall be able to secure and retain a better and more contented class of workman than we would be able to obtain in what otherwise would be an isolated and unattractive area.'[9] Its location was dictated more by the immediate need to construct Maraetai, only two miles away, than by longer-term planning. The town was built on desolate and barren scrub-covered pumice land leased from Ngati Kahungunu.

As work at Karapiro wound down in 1946, men were transferred to Mangakino. By now the wartime manpower regulations were no longer in force and the ministry had to provide more attractive conditions to assemble and retain a workforce. Until a road was put through from Tokoroa the only access was by a two-hour journey along a pumice track and then, until a bridge was built in 1946, across the river by punt. Unlike previous camps, the layout of Mangakino was planned as a whole, with a commercial and civic centre, sealed roads (both curved and straight) in the residential areas, footpaths and electric reticulation. The civic and shopping centre was to consist of modern and substantial



Mangakino, Semple's model construction town, was built on desolate and barren scrub-covered pumice land from 1946 onwards. In the foreground are traditional works camps, in the centre are the town's sports facilities surrounded by new housing, and beyond the Waikato River there are rapidly growing pine forests.
Whites Aviation

buildings, and there were to be a post office, a telephone exchange and a bus station. The New Zealand Workers' Union played an active role from the beginning in decisions about accommodation and recreational facilities. Improved houses were designed as a result, with larger windows, built-in washing facilities, and bathrooms and kitchens separate from the living-room. Older huts transferred from Karapiro were upgraded to include a wash-house/bathroom and a kitchen area for each hut.

By 1947 some 300 houses had been built or transferred to the site. There were also single men's camps and hostels. In 1948 there were 500 houses. The town was growing so rapidly that services and amenities could not be installed fast enough. Families had to wait for lighting, heating and inside water. Roads remained unsealed and this, together with extensive development of the surrounding land, meant that any wind created dust-storms of pumice that dirtied washing and penetrated everywhere indoors. Shops were slow to open, the first block not being completed until 1948. For some time there was no doctor, only someone providing first aid. When the doctor arrived in February 1947, he was paid by the Health Department and the work-force had free medical care.

The town's population reached 3,000 in 1949, 4,300 (in some 800 houses) in 1950, and more than 5,000 in 1952. The guarantee of continuous employment and housing attracted more married men than had worked on previous projects. This had the advantage of lowering annual labour turnover drastically from the usual level of three-quarters or more of the work-force down to little more than one-quarter, and meant that the town had a very young population and one of the highest birth rates in the country. It was decided to build a maternity hospital, which opened in December 1948. From 1946 there had been a small primary school operating in a large hut. In 1948 a district high school was established, and by 1954 this had become the largest in the country. By 1952 the town had come of age, with recreational and civic amenities that compared favourably with any other community of its size. It had a cinema, concert hall, library, gymnasium and extensive sports grounds.

YMCA-run recreational facilities were not thought to be appropriate for a larger, more permanent construction town. It was felt that the YMCA should restrict its activities to spiritual matters, and that the time had come for a more popular initiative from the work-force itself.

In 1946 the Waikato Hydro Recreation and Athletic Association (later the Waikato Hydro Welfare Association) had been formally constituted in the Karapiro camp, 'to assist in the provision of facilities for, and encourage the participation in Athletics, Games, and such Sports and Social Recreations as may from time to time seem desirable and which in the opinion of the Association's executive would be for the welfare of the communities of the Waikato Hydro Electric Power Schemes'.[10] This organisation was transferred to Mangakino and, after negotiation with the Ministry of Works, took over the role of the YMCA. The ministry handed over to it control of all halls and other facilities, including sports fields.

The Welfare Association became the key body mediating and liaising between the ministry and the work-force. Delegates to the association appointed from all affiliated bodies voted annually for a management committee. The association was largely financed by the very profitable operations of the cinema. It published the weekly *Mangakino Chronicle*, which had a circulation of more than 1,100, and in general saw as its goal the bringing about of 'a standard of social life in keeping with modern concepts of decent citizenship'.[11] This was the only form of local government, since there were no ratepayers and no local authority; the Ministry of Works, 'Uncle MOW', was both landlord and employer. The Welfare Association, the Maori Tribal Executive, Maori wardens and police were the other major authorities in the town. The fact that the constable who had served at Karapiro moved to Mangakino was apparently helpful. A 'Householders' Association' and the New Zealand Workers' Union were also important organising influences. The Householders' Association was formed in 1948 to assist in improving amenities and services, and disbanded once this had been accomplished.

The town did have its share of conflict and divisions. One area was known as the 'staff end'; here salaried Ministry of Works staff rented superior housing with better amenities. Industrial relations between senior Ministry of Works engineers and the Mangakino branch of the Workers' Union were not good, and for a number of years Mangakino seemed synonymous with industrial disturbance and protest. A Mangakino branch of the Communist Party was formed early in 1947, and for most of that year its publication, the *Mangakino Spark*, was the only local newspaper. Party members were amongst those most active in the local Workers' Union branch. L. Clapham, a tunneller, was for a time both publisher of the *Spark* and its main writer, and the local secretary of the Workers' Union. He fought the 'class war' against both the engineers ('representatives of capitalist forces') and the Ministers of the Labour government. Clapham had worked at Karapiro; the engineer now in charge of Waikato development had known him there and refused to have him at Maraetai until ordered to do so by Semple, who was himself under pressure from the Workers' Union. At the same time the Minister warned Clapham that if he lived up to his reputation as a troublemaker he would be 'down the road' immediately.

The engineers believed that Clapham continually fomented industrial disruption for political reasons but was clever enough to avoid dismissal. In particular, he was seen as responsible for the failure to introduce a seven-day roster to speed up work in the diversion tunnel. Early in 1947 several engineers handed in letters of resignation, saying that they would not work at Maraetai if Clapham continued to be employed there.

Clapham's disruptive tactics had now outworn Semple's limited patience and he permitted the Commissioner of Works to transfer Clapham to Auckland 'in the interests of industrial harmony'. The union tried to resist this and an Emergency Disputes Committee was set up. On the vote of the presiding judge this decided that the transfer was both legal and justified by the contents of the *Spark*. A ballot of Workers' Union members resulted in a narrow decision to strike from 11 March 1948. The government, believing that the strike was a 'Communist plot', was determined to see matters through, Semple arguing that it was a trial of strength in which the state must prevail. After a month the Minister of Labour set up a tribunal to settle the dispute, the men returned to work and Clapham was temporarily reinstated. The tribunal found in favour of the Commissioner of Works, but this time Workers' Union members decided not to strike and Clapham left.

Relations remained strained after Clapham's departure, as the new union secretary was also a Communist. Delays were caused by shortages resulting from a strike by cement workers. In 1950 there was widespread industrial unrest throughout the country because of the rising cost of living and the removal of subsidies on basic food items. On 27 February 1951 the Mangakino branch of the Workers' Union went on strike in sympathy with the watersiders and in opposition to the drastic emergency regulations, which were the government's response to the waterfront dispute. There was no work at Maraetai or Whakamaru until 30 March, when the workers voted by secret ballot to go back. Hydro-electric construction in general was seriously set back as a result of this dispute. Bad relations between the Ministry of Works and the Workers' Union continued until the mid-1950s, but there were no further major conflicts.

Mangakino was intended to be, in Semple's words, a 'semi-permanent town'. What this meant gradually became clear. Over more than a decade the town was reprieved several times as new Waikato projects began. Each time a scheme neared completion there was an air of suspense. The town was totally at the mercy of government policy, and it was never certain until the last minute whether the next project would be authorised. By the time that Maraetai was winding down, Whakamaru was well under way, and in 1953 first Waipapa (which was to be halted for a time) and then Atiamuri were started. Only some of the Atiamuri workers were accommodated on the site, many being transported from Mangakino. In 1955 the development of the Waikato was accelerated as full-scale construction went ahead at Waipapa, and Mangakino's future seemed more optimistic. Whakamaru was completed in 1956, but work then began on Ohakuri.

In 1959, the year that Atiamuri was completed, the Labour government started Maraetai II. This was a great boost to Mangakino, and its population began to increase again. In late 1959 it was decided to go ahead with Aratiatia, and although workers lived elsewhere, this did help to keep the town going at a time when the Ohakuri and Waipapa projects were winding down. Mangakino's population fell only gradually from a peak of 6,400 in 1959 to about 5,200 in 1961. However, the abrupt cancellation in 1961 of Maraetai II, which affected 500 workers living in Mangakino, caused a rapid decline in both the town's spirit and its population. Feelings ran high, and at a meeting addressed by Hugh Watt and the local MP a motion of no confidence in Goosman and the government was passed by the 2,000 people present. The Workers' Union protested that it had been promised a further three years' work on the river. By the end of 1963 the town's population had fallen to 2,000. Houses became empty and were removed, and many clubs, societies and other groups were wound up. However, the town survived. The many roads and bridges built in association with the Waikato projects had opened up the surrounding area, and this had led to the establishment of some 80 dairy farms that looked to Mangakino for services.

Maraetai I and II

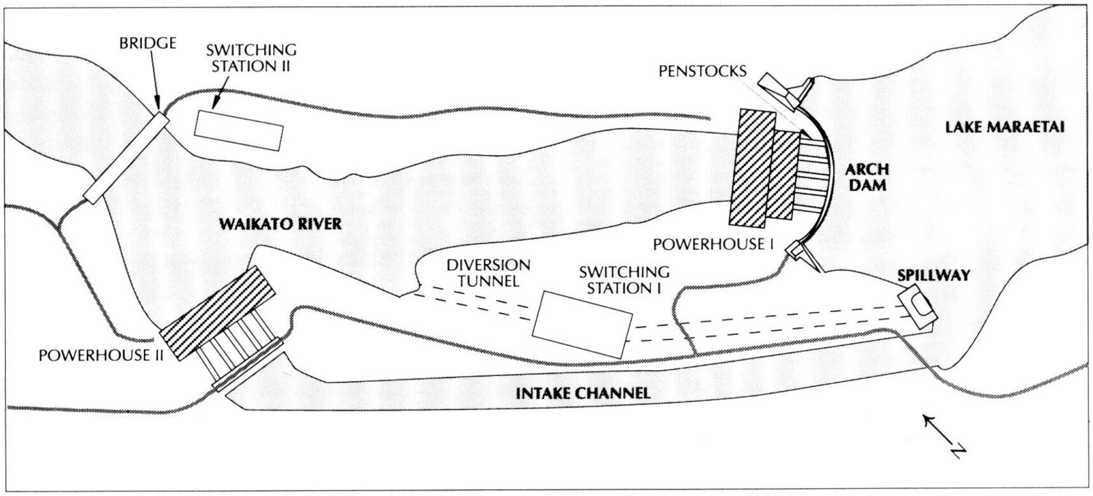
Semple announced the plans for the full development of the river in 1946.[12] The intention at first was that the Ohakuri site, closer to Lake Taupo, should be developed after Karapiro, followed by Whakamaru and Maraetai further downriver. This was based on the apparent suitability of the narrow gorge at Ohakuri. Then for a time Whakamaru became first choice, as being much the best focal point for feeder lines from other stations on the river and the ideal centre from which to transmit power over the new 220 kV line. But more investigation had been done for Maraetai, and starting Whakamaru first would make it more complex to divert the river for Maraetai later. It was decided to build Maraetai first, some twenty miles upriver from Arapuni.

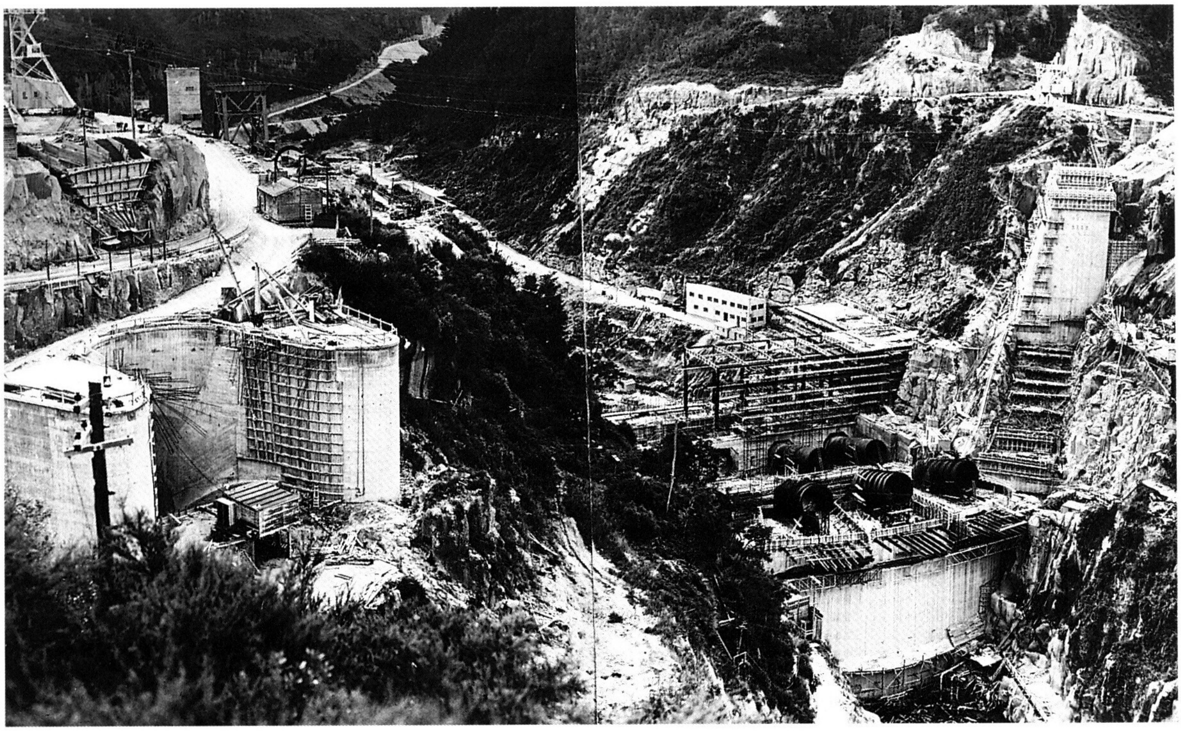
Investigations between 1940 and 1945, culminating in detailed surveys and examination of foundations, led to a proposal to build an arch dam in the deep and narrow gorge. Construction work began in 1946, and an access road was put through from Tokoroa to the site. Much of the earthmoving was done by owner-driver contractors using trucks with a capacity of three yards; later models could carry up to eight yards at a time. Bulldozers broke up and moved the earth, and mechanical shovels loaded it into the trucks. 'Carry-alls', such as the Euclid (which had a capacity of nine yards), were also used extensively to scoop up the soil.

Because of the narrowness of the gorge, the powerhouse took up the entire length of the base of the dam. This meant that the spillway had to be designed as part of the diversion tunnel. It was clear that extensive grouting would again be required, as the volcanic ignimbrite rock had cracked extensively when it cooled. Maraetai was meant to be completed in 1951, but this target proved unrealistic because of failed delivery dates, shortages of labour and construction materials, industrial unrest and the extreme difficulty of some of the work. The Public Works work-force at large was less than two-thirds of its pre-war strength, and there were many thousands of vacancies. Although hydro-electric development was given special priority in access to materials, the reality that local companies could produce only two-thirds of the concrete required and steel imports were at only two-fifths of their pre-war

Maraetai I: Constructed 1946–53. Head 200 feet. A concrete variable-radius arch dam, 436 feet long and 285 feet high. Five turbines drive 36 MW generators, making the total capacity 180 MW.

Maraetai II: Started 1959–61 and then shelved; completed 1967–70. Head 200 feet. An additional station parallel to the river and downstream from Maraetai I. A long intake channel runs alongside the river, and penstocks lead water down a cliff to the powerhouse. Five 36 MW generators were installed, making the overall capacity of both stations 360 MW for peak-load use.

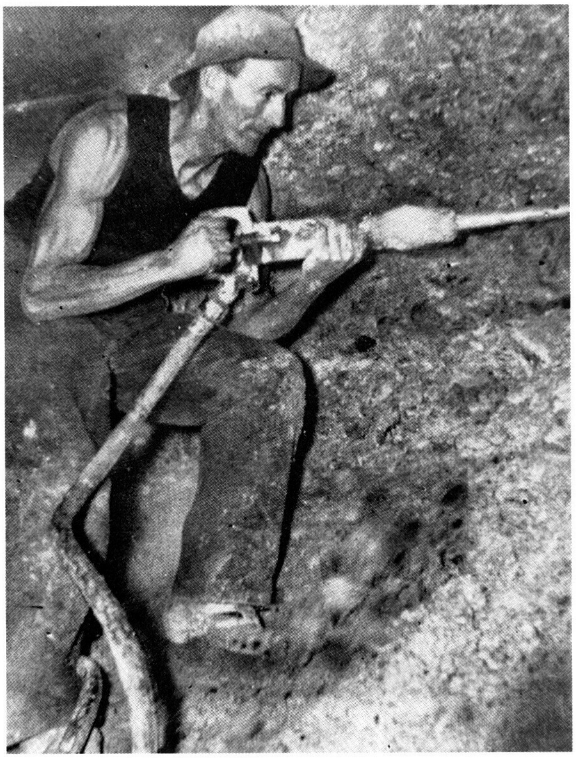




Maraetai was built in a deep and narrow gorge, which meant that the powerhouse took up the full length of the base of the concrete arch dam. The spillway thus had to be designed as part of the diversion tunnel. In this photograph taken in 1951 the entrance to the spillway tunnel, which dropped down to the diversion tunnel at an angle of 45 degrees, can be seen at the left. To the right the dam has reached its full height at the right abutment. The penstocks and powerhouse behind have made good progress.
Alexander Turnbull Library

levels made the problem insurmountable.

The diversion of the river was particularly difficult. The circular diversion tunnel, which was 25 feet in diameter and 1,685 feet long, was begun in late 1946, but was slowed by the large amounts of water that poured into it until it was extensively grouted with cement and bitumen and lined with concrete. By 1948 some 800 workers were on-site, and the diversion was completed in March 1949 when the passage was 'opened up by two spectacular explosions which broke up the rock barriers left at each end between tunnel and river'.[13] The Waikato's level was lowered by shutting the Taupo control gates, and eleven bulldozers worked frantically to push spoil into the river to dam its natural channel, form the lower coffer dam and force all the water into the diversion tunnel. Unexpected heavy rain created a flood that advanced downriver, causing efforts to



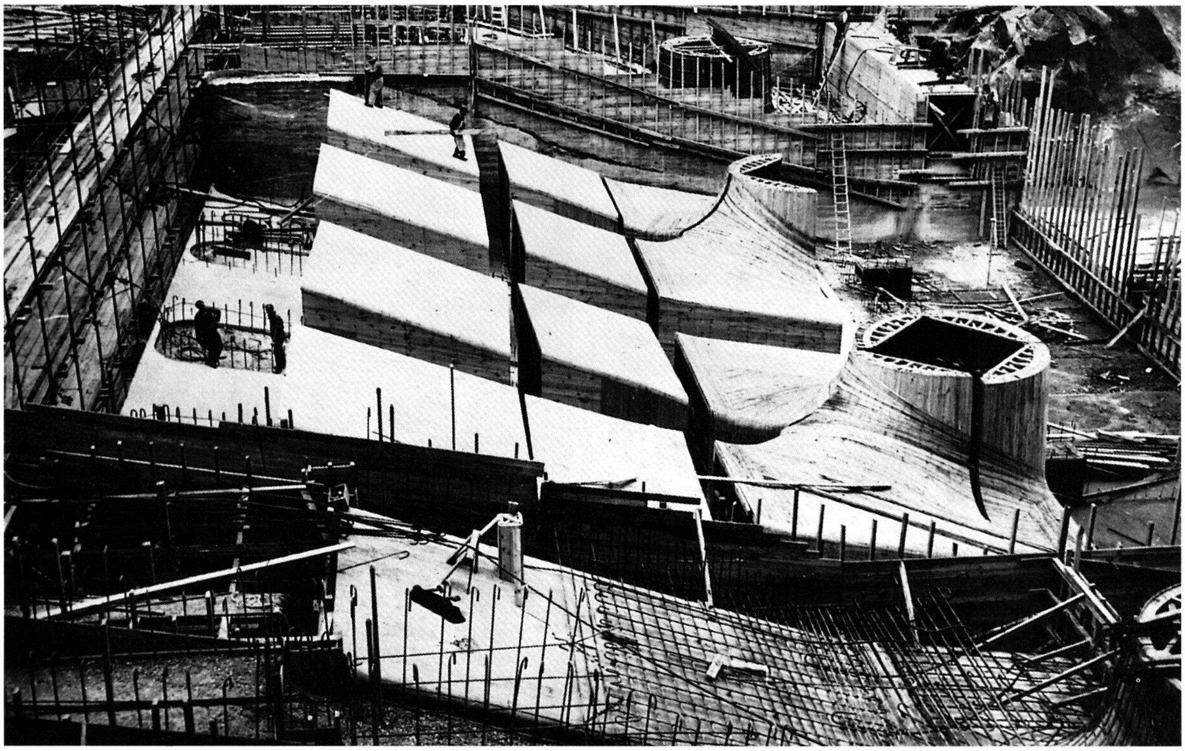
Maraetai's diversion tunnel, begun in late 1946, was a difficult job not finished until March 1949. Here a tunneller uses a pneumatic drill. They often worked knee- or even waist-deep in water.
Hydro-electric Power, State Hydro-electric Department, *c.* 1949

be redoubled. After 27 hours of work, with the river rising all the time, the gap was finally bridged with a huge rock. This dramatic activity was filmed by the National Film Studios. The flood hit the diversion hard, but it held.

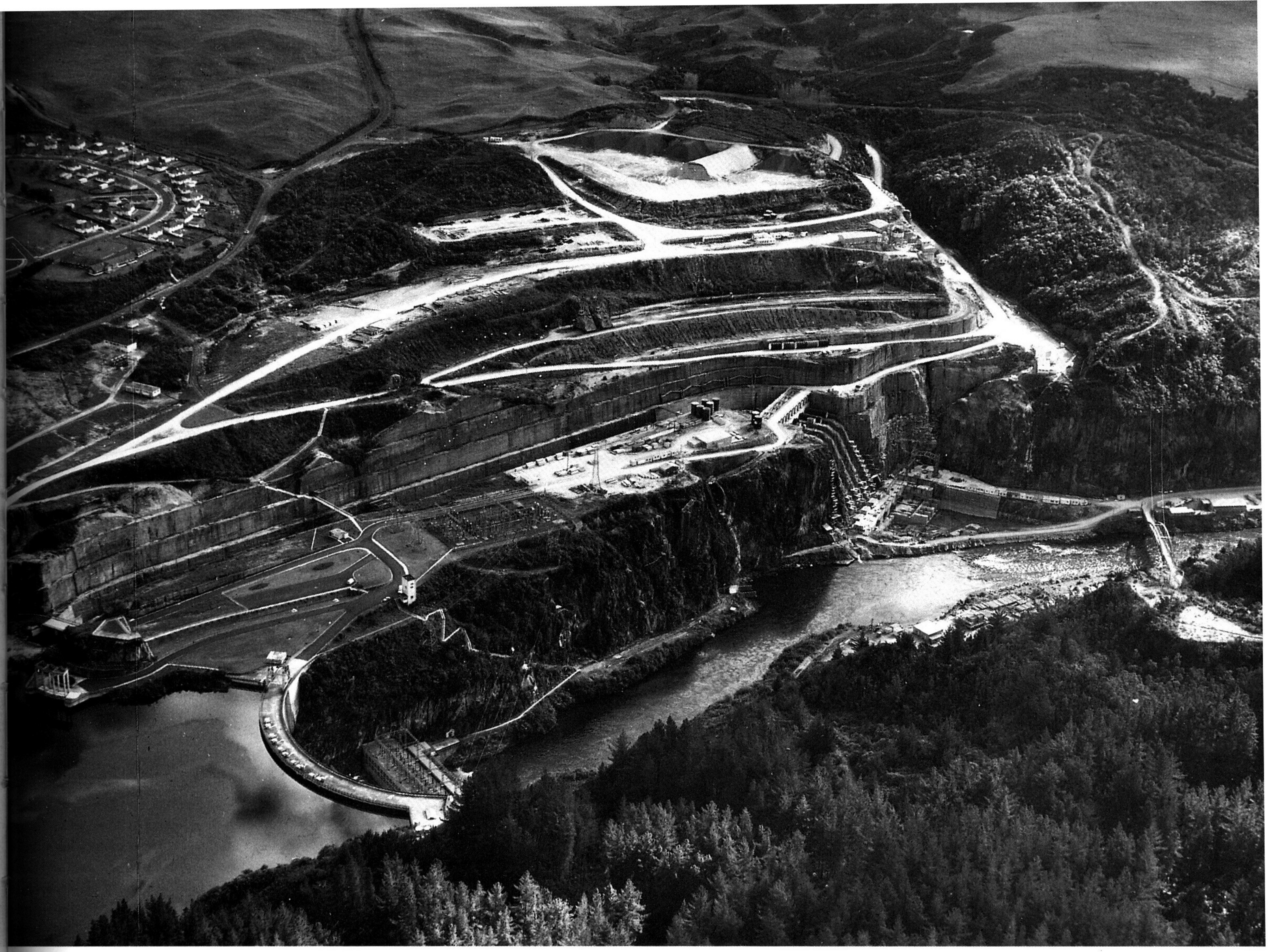
Work then began on the spillway tunnel, which dropped at a 45-degree angle to intersect with the diversion tunnel. At the end of 1949 work was started on the dam foundations, which required extensive and careful grouting of the foundation rock for some 200 feet below the foundations and the creation of a 1,000-foot 'curtain' on both sides of the dam site. A huge number of holes were drilled and more than 11,000 tons of cement used in this process. Concreting of the dam began in September 1950, a large mechanised batching plant having been installed to produce the more than 200,000 cubic yards of concrete required. For the first time in New Zealand a system of cooling mass concrete was used, involving imbedded pipes through which refrigerated water was passed. The work-force now reached a peak of 1,200. In July 1951 a major flood overtopped the upper coffer dam but did no serious damage.

The department's engineers wanted to go outside Britain for major equipment because of tight delivery dates and British firms' lack of experience in the manufacture of large turbines and generators and 220 kV equipment. The British tenders all turned out to be similar, and two-thirds higher than others, so the contract for generators was awarded to Canada and that for turbines to the United States. The three lowest tenders for the spillway gates and frames came from West Germany, one of them being a third below any other and with delivery promised a full year before the lowest British offer. It was recommended that the two lowest German bids be accepted, and perhaps surprisingly, Cabinet agreed to this.

The powerhouse went up rapidly. Its design, which incorporated a structural steel frame and a precast concrete section roof, was dictated by the necessity to have the machines operating as soon as possible. The transformer station was built at the back and on top of the powerhouse itself because of the confines of the gorge. Concreting of the foundations began early in 1950. A year later the penstocks were constructed and the first three machines were installed. The station began operating on a reduced load and on half head, producing 30 MW, on 31 October 1952. The reduced head was maintained while the diversion tunnel was stopped with a huge concrete plug



At Maraetai the draught tubes were cast in concrete. Here the timber formwork sections are being assembled in 1950.
Auckland Star, Alexander Turnbull Library



This panoramic view, *c.* 1967, shows the completed Maraetai I station (at left) and the earthworks and concreting being undertaken in preparation for the construction of the long-delayed Maraetai II. The second station involved a long intake channel running alongside the first station to very steep penstocks leading down a cliff-face to the powerhouse at its base. The penstock slopes can be seen clearly at middle right.

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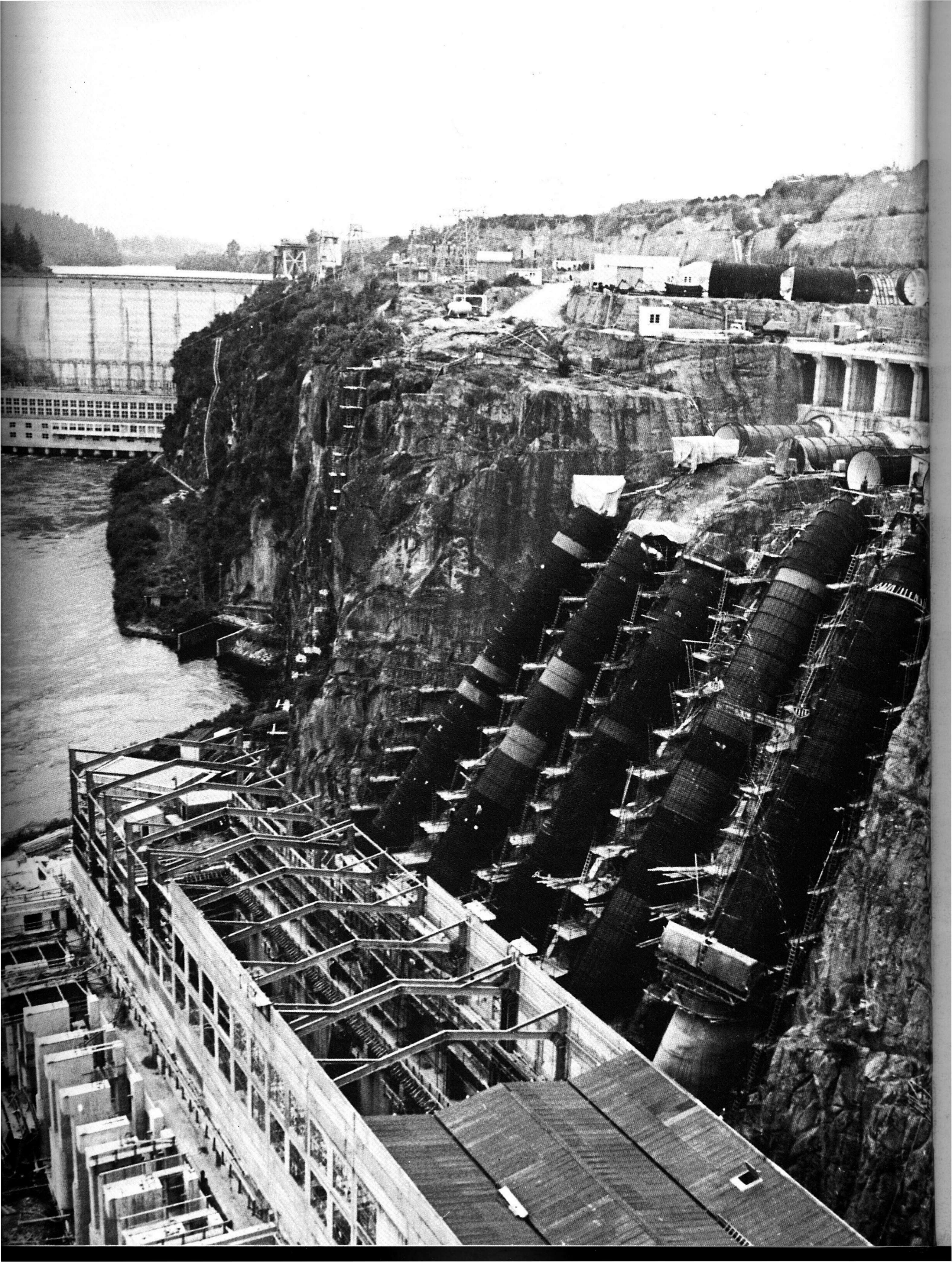
about 100 feet long. Temporary flumes acting as spillways carried the water from the other two penstocks through the powerhouse.

In April 1953 the head was raised to 175 feet, and the station was officially opened on 5 September 1953. The last two machines were installed in January and April 1954, and the level of the lake was raised to its full height. Maraetai was now the largest power station in the country, with a capacity of 180 MW.

In Hugh Watt's 1958 White Paper the proposed peak-load Korokoro gas-turbine station was replaced by the duplication of Maraetai's 180 MW by a new peak-load station to be built adjacent to the existing one and producing its first power by May 1963. Maraetai II, as it became known, was intended to complement the base-load Wairakei and Meremere stations. It was politically controversial from the start.

Approval for the project was given in April 1959. Large-scale rock excavation was required to make a forebay channel beside the existing dam; the penstock intakes were to be on the cliffs downstream from the existing spillway tunnel. Work began in late 1959, much of the excavation being carried out rapidly by rock rippers and large scrapers. The first two 36 MW units were ordered in December. By early 1960 almost a million cubic yards had been excavated from the headrace, the intake work was almost finished, and the penstock slope excavations were half complete. Some 500 men were employed on the project at



this time. In the following year another 680,000 cubic yards were excavated and virtually all the site preparations including powerhouse excavations were completed.

With the election of a National government in 1960, the political parameters of power planning changed again. The incoming government had an eye for making economies. Its confirmation of the Cook Strait cable project, together with the additional machines planned for existing Waikato stations, led to the shelving of Maraetai II. Work ceased in September 1961 after half a year's concreting had been done, the machines that had been ordered went to Matahina, which was now advanced by two years, and the 500 employees went initially to Aratiatia and later to Matahina.

Because of an exceptional increase in consumption in the year ending March 1964, the Power Planning Committee resurrected the Maraetai II project in 1964, with its first power designated for April 1970, when the planned Western Diversion stage of the Tongariro development would increase water flow down the Waikato. This made more sense than the original conception of the project, under which there would have been limited water for peak-load purposes only. Services and accommodation were re-established on-site in 1967 and the powerhouse excavations were dewatered. Construction of the powerhouse foundations and penstocks resumed, and by early 1968 the civil engineering work was three-quarters complete, the erection of penstock liners was nearly finished and the powerhouse was well advanced. The huge headrace was being lined with concrete. In 1969 generating units and turbines were installed, and the first two units were commissioned on 10 July 1970, almost on schedule. The third unit was commissioned in September, the fourth in November and the fifth in February 1971.

The two stations are treated as one with a total of ten machines, but because of the limited storage, all ten are used only rarely, at times of peak demand; it is more usual for some six or seven units to be in operation.

Opposite: By September 1968 Maraetai II was almost finished. At upper right is the concrete intake, from which steel penstocks lead down to the powerhouse. The Maraetai I diversion-tunnel outlet can be seen between the two stations.
Waikato Times

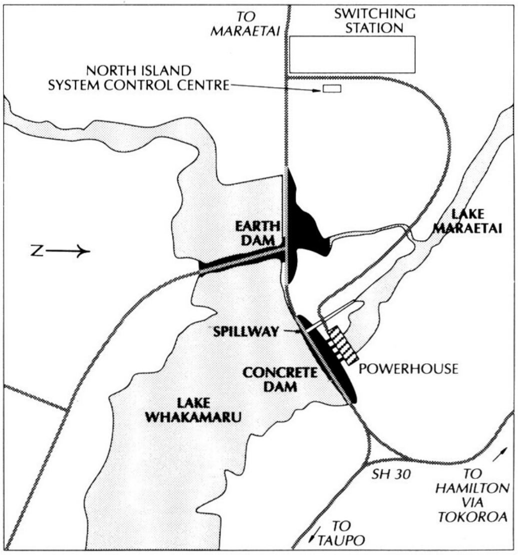
Whakamaru

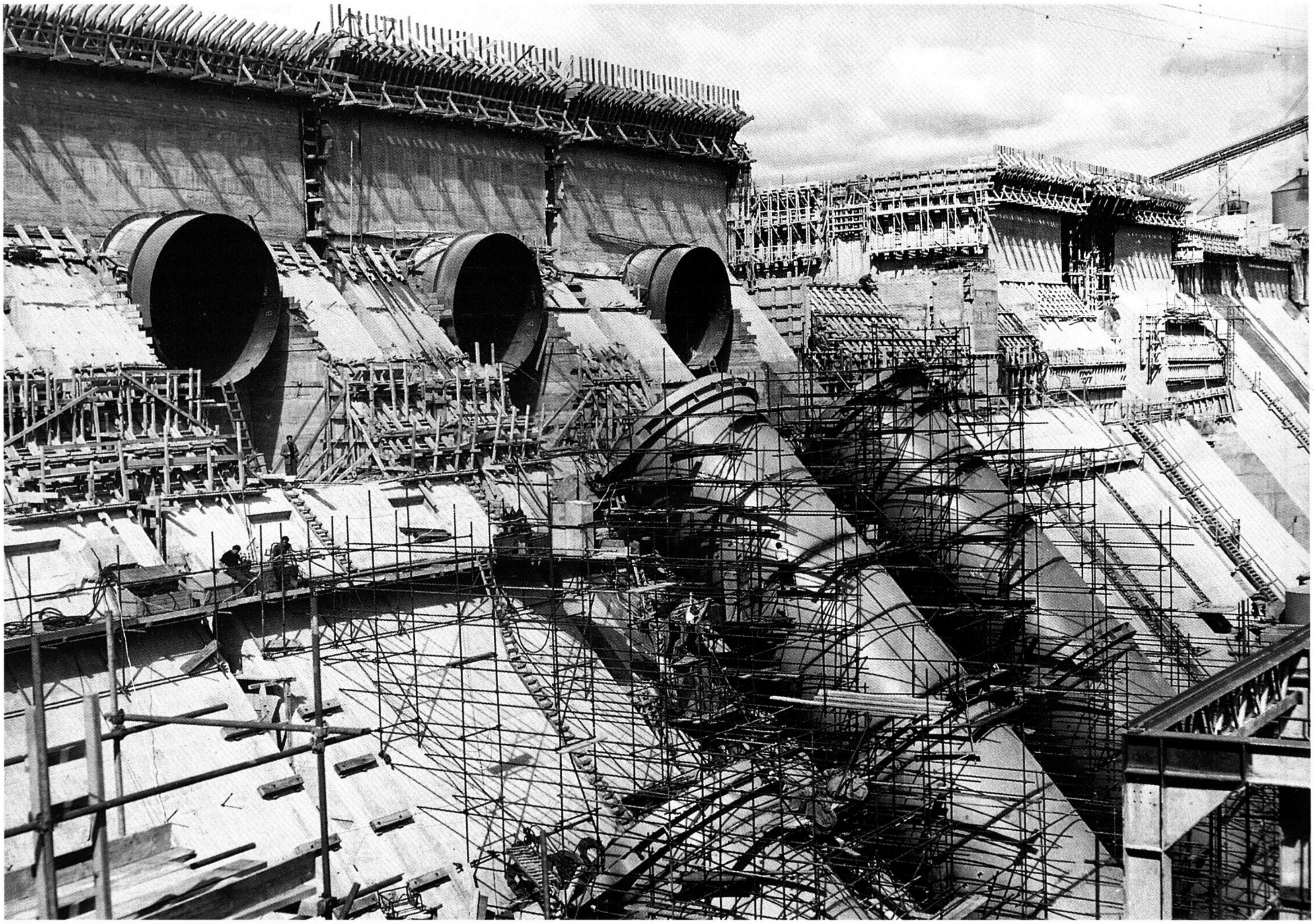
After initial investigations at Whakamaru, four or five miles upriver from Mangakino, in the period 1940–44, intensive work was undertaken from 1946 until 1949.[14] The Whakamaru area was geologically complex and several sites had to be considered carefully. Many hundreds of holes were drilled and more than 30 shafts sunk before the final site was chosen.

The large diversion channel, 850 feet long and up to 100 feet deep, was begun in December 1949 and completed in November 1952 after the removal of 122,000 cubic yards of ignimbrite rock and considerable grouting. At this point construction was delayed by the late arrival of two aerial cableways and the concrete-batching plant from England. The downstream part of the channel was concreted and subsequently formed part of the spillway, while the remainder, underneath the dam, was closed by a large sluice gate. Meanwhile excavation for the dam abutments was proceeding.

With diversion completed, the dam foundations

Whakamaru: Constructed 1949–56. Head 124 feet. A central concrete gravity dam, 1,106 feet long and 184 feet high, contains the penstock intakes and spillway. There is an earthfill dam, 1,299 feet long and 93 feet high, at the western end, and earth cut-off walls at each end of dam. Four steel penstocks lead water to the powerhouse directly below the dam and to four turbines driving 25 MW generators. Total capacity is 100 MW.





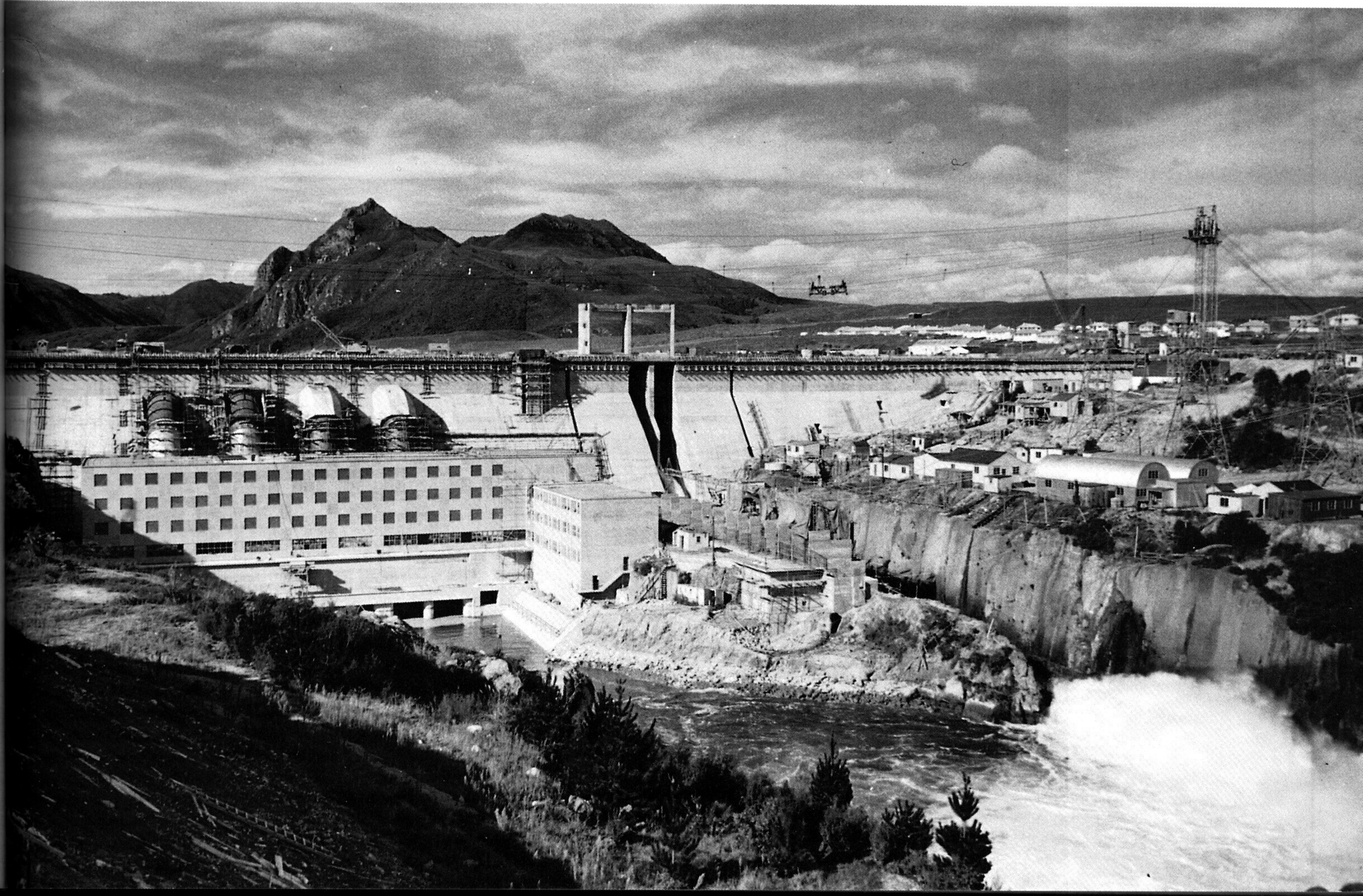
were excavated down to solid rock and the many deep, clay-filled cracks were extensively grouted. This complex task, entailing nearly 6,000 feet of shafts and drives and 9,000 cubic yards of concrete, caused considerable delays. An innovative feature of the earth section of the dam was the use of crushed ignimbrite for its core.

At the end of March 1956 the sluice gate was closed and a start was made on filling the lake. This took until early May because it had to be emptied again when problems with the diversion-channel gate were discovered. Monitoring of the foundation rock, which had caused concern because of its elasticity, found it to have tilted less than had been expected, and the first two machines were commissioned ahead of schedule in May 1956. There was urgency because of the need to meet winter peak loads. The other two machines were installed later in the year, bringing the station up to its full capacity of 100 MW.

Above: As the concrete dam goes up at Whakamaru, the four large steel penstocks are installed.

Opposite above: Whakamaru was a combined concrete gravity and earth dam. The central concrete section and the earth section filling a gully at right can both be seen. Another earth section remains to be built on the left. The large diversion channel is underneath the right part of the concrete dam, and the powerhouse is on its left.

Opposite below: The Whakamaru concrete dam and powerhouse are now virtually completed. There is a considerable flow through the diversion channel, which subsequently became part of the spillway.

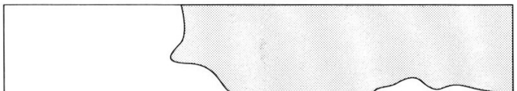


Atiamuri

It was clear that the design staff available in New Zealand could not cope with all the Waikato projects at the speed required.[15] A geophysical survey of the Atiamuri site had been undertaken in 1947–48, and by 1950 investigations were complete. In August 1950 Cabinet gave approval in principle for Atiamuri, Ohakuri and Waipapa, the first two to be designed by overseas consultants. (In the end Ohakuri was designed by the Ministry of Works.) Initially, Goosman also wanted these schemes to be constructed by overseas contractors. In 1952 the English firm of Sir Alexander Gibb and Partners, in association with another English company, Merz and McLellan, sent out staff to design Atiamuri (which originally was to have only three turbines, a fourth being approved in 1958). The decision to employ consultants caused some consternation amongst Ministry of Works engineers who had just finished designing Whakamaru and were looking for work. When permission to call tenders was sought early in 1953, Treasury baulked and sought deferral of the project for at least a year. This, however, would have increased the risk of shortages later in the decade, and the government gave its approval in September 1953.

Construction work began immediately. The site and a considerable area of pine forest were cleared, a camp was erected, and access roading and a new high-level bridge across the Waikato were constructed. The main highway was realigned and a road was built to Whakamaru to make a link with Mangakino. The camp comprised more than 350 single men's huts, 100 married men's houses, and 30 houses for salaried staff, and had a cinema, a 'dry' canteen, a library and a recreation room.

Atiamuri: Constructed 1953–59. Head 81 feet. It comprises a concrete gravity dam, 560 feet long and 143 feet high, with an earth wing 840 feet long, and at maximum 100 feet high, at the left bank. Four steel penstocks take water to turbines driving 21 MW generators. Three units were installed in 1958–59 and a fourth in 1962. Total capacity is 84 MW.

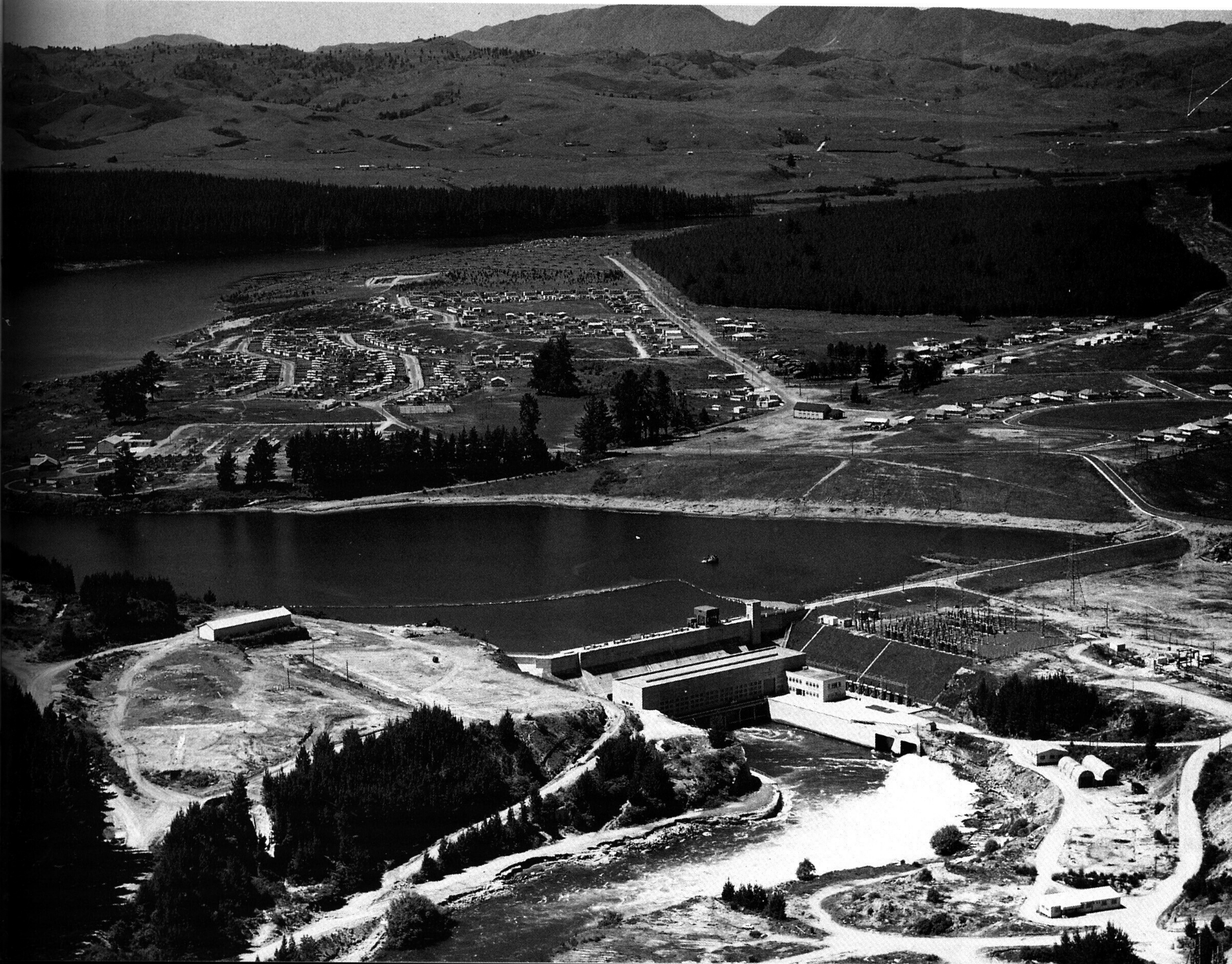


Twin diversion culverts about 450 feet long were completed by the end of 1956, and the river was diverted into them in January 1957. One culvert was subsequently converted into a high-level spillway, while the other was closed. The river was quickly blocked with large boulders and gabions, providing a coffer dam within which excavations could proceed.

The foundations were once again of crucial importance. Only part of the dam could rest on a dome of very hard rhyolite rock that, when strengthened by the inevitable grouting, would support a concrete gravity structure. The remainder was to comprise an earth dam, and finding a secure foundation for this proved difficult. Excavation for the concrete section went some 40 feet below the original river bottom, and the foundation work in an old riverbed for the earth dam was complex. It required an open cut of an average depth of 60 feet down to the ground-water level and the shifting of some 300,000 cubic yards of porous gravels, with a watertight concrete cut-off wall extending down through the sand, gravels and boulders to be keyed into firm pumice breccia. Curtain grouting continued for 30 feet below the foot of the cut-off

Opposite above: The construction of Atiamuri involved the felling of a large section of pine forest and realignment of the main highway. A dome of rhyolite rock was adequate for a concrete gravity dam (centre), but the section to the right had to comprise a lower earth dam. By the time this photograph was taken in September 1958, both parts of the dam, together with the powerhouse, were largely completed. The concrete-batching plant is to the left of the dam, and behind is a substantial public works camp and permanent village.
Whites Aviation

Opposite below: Atiamuri is completed, its lake filled and the public works camp in front of the village has largely disappeared. The two diversion culverts can be seen to the right and downstream of the powerhouse. While the left-hand one was closed off, the other was used as a high-level spillway and is in operation here.



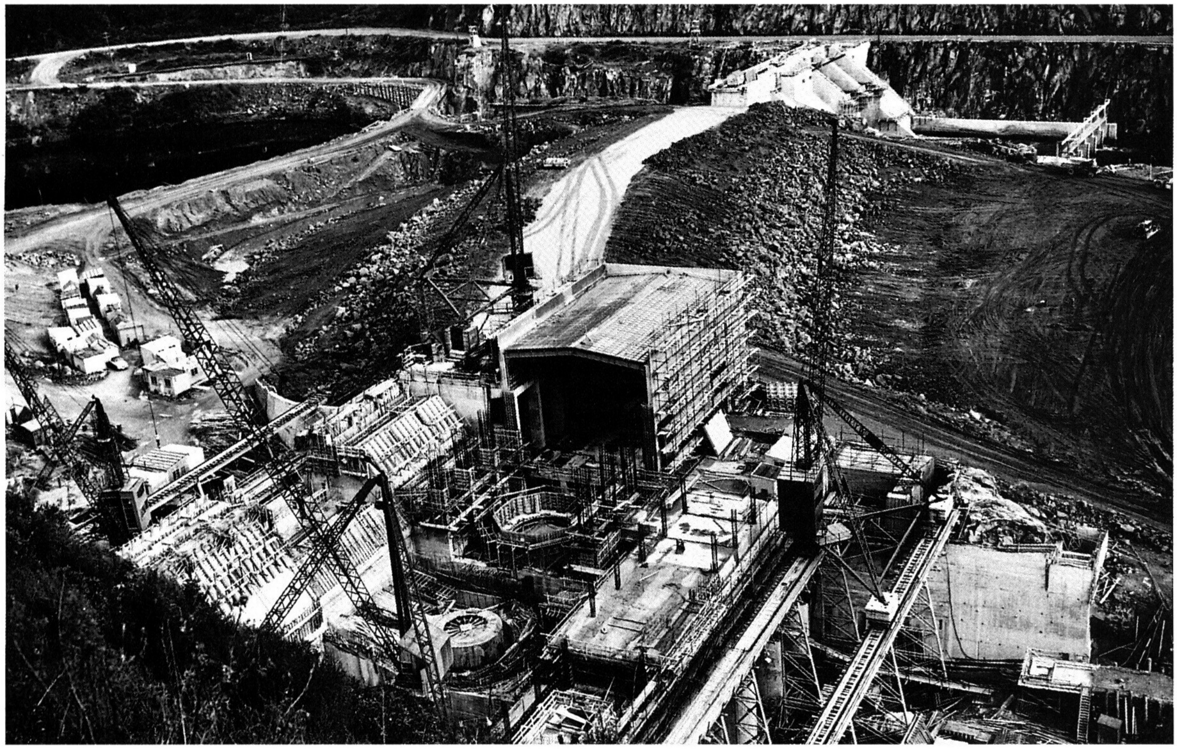
wall. The considerable drainage problems were dealt with by extensive drives and shafts.

Meanwhile the powerhouse was constructed in the gorge just below the dam. The first machine was commissioned on 17 November 1958, some six months ahead of schedule, the second in early December and the third early the following year. (A fourth unit was installed in 1962.) With Meremere having been commissioned at much the same time, and heavy rainfall in the Waikato and Waikaremoana catchments, the post-war restrictions on electricity use in the North Island were at last lifted by Christmas 1958. The power planners were given some respite, but knew that the development of the Waikato had to continue if the inexorably expanding demand was to be met.

Waipapa

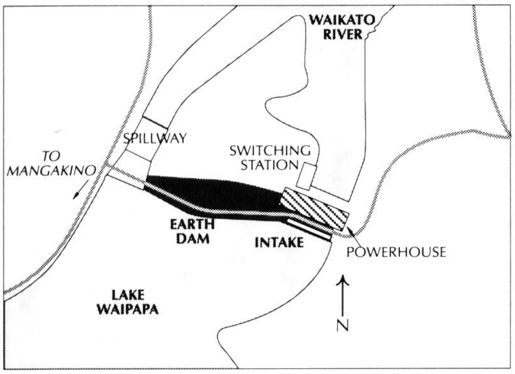
Waipapa, at the head of Lake Arapuni and seven miles downstream from Maraetai, was the smallest of the Waikato stations. It had been under consideration since 1943 but was extremely problematic because of the difficult foundations in the riverbed.[16] The river had cut its way through the ignimbrite of the area and into alluvial material underneath. On the chosen site there was a 60-foot-wide ledge or bridge of ignimbrite that, it was decided, could form the basis of the foundations. After exhaustive investigations of some seven sites over four miles of the river between 1948 and 1950, Waipapa was put aside for the time being because of the site problems and a decision to divert some resources to geothermal development. Subsequent doubts that the ignimbrite would support a concrete dam led to a proposal for an earth dam, the core of which would rest on the bridge while its shoulders were supported by the alluvial material. Construction in these conditions was to be a considerable achievement, although the full extent of the difficulties were not apparent at this stage. The dam was to contain nearly half a million cubic yards of sand, gravel and ignimbrite.

The scheme was finally approved in 1953 and some initial work was done, but full-scale construction was delayed by the need to reduce overseas expenditure, by the complexity of the site and because work on Wairakei took priority. Construction did not begin until April 1955, when the 1,700-foot-long diversion channel was excavated.



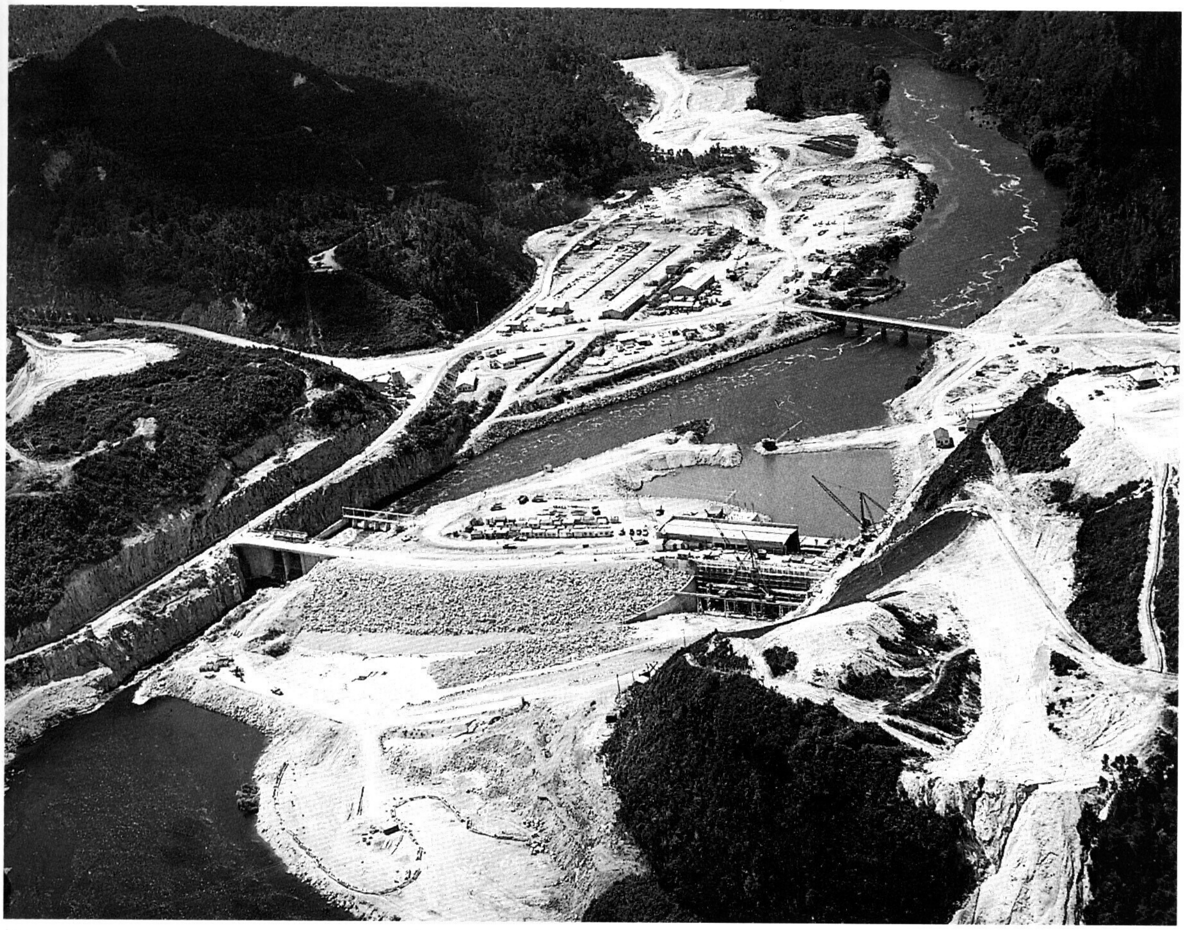
Because of extremely difficult foundation conditions, Waipapa was designed as an earth dam resting on a narrow rock bridge. Here the concrete intake and powerhouse structure is shown in the foreground, with the earth dam and concrete spillway section behind.
Free Lance collection, Alexander Turnbull Library

Waipapa: Constructed 1955–61. Head 53 feet. An earth dam, 525 feet long and 121 feet high, has three concrete penstocks incorporated into its structure. Three Kaplan turbines drive generators of 17 MW, producing a total capacity of 51 MW.

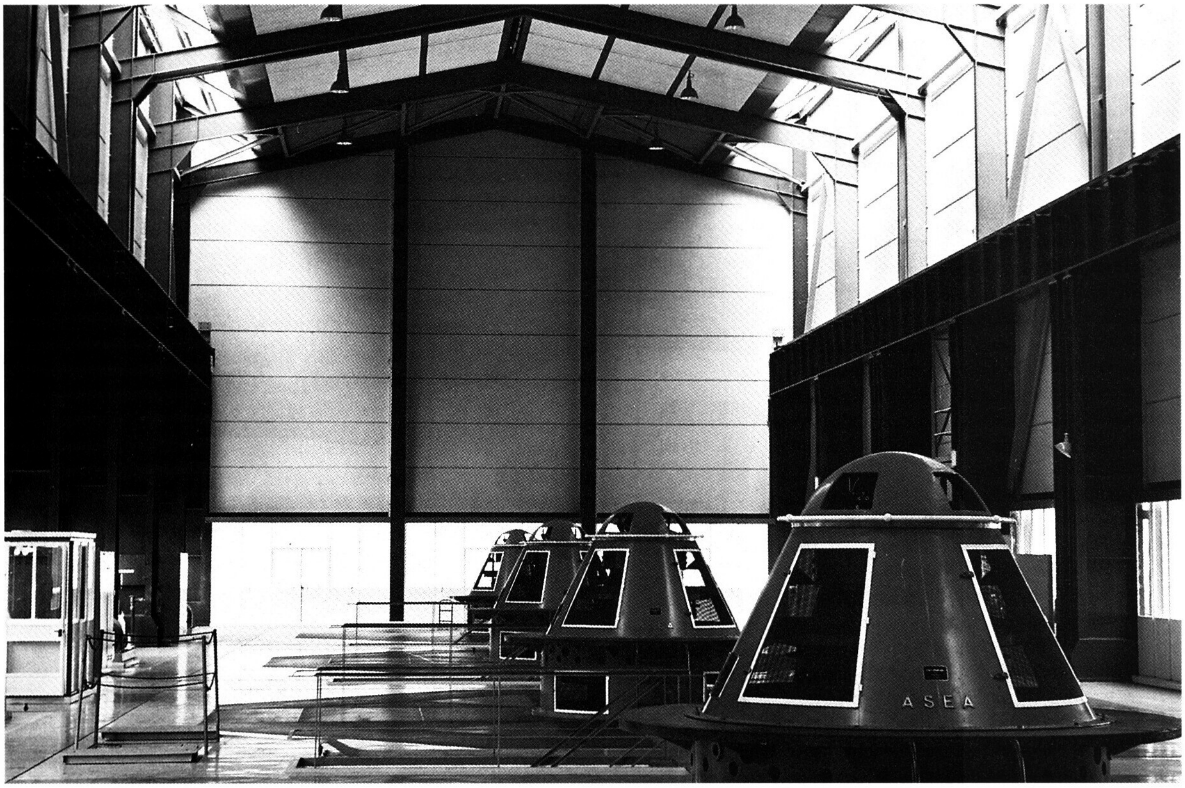


Work proceeded slowly, since it was discovered that the ignimbrite bridge was overlain by some twenty feet of soft silt. Extensive tests were needed to ensure that this silt would support the shoulders of the dam. The main construction plant was not erected until 1957, by which time the diversion channel was being concreted. The river was diverted in November 1958, and by early 1959 foundations for the powerhouse had been excavated and concreting had begun.

Over the following year the difficult task of excavating down to the rock bridge was completed. This involved cleaning out large gullies and crevices by hand, and extensive grouting, to provide a surface suitable for dam core material. The grouting used nearly 6,000 cubic yards of concrete. By early 1960 half of the dam's core had been placed, while a year later, with about 400 employed on-site, both the dam and the powerhouse had been virtually completed. Power was first fed into the network on 10 April 1961.

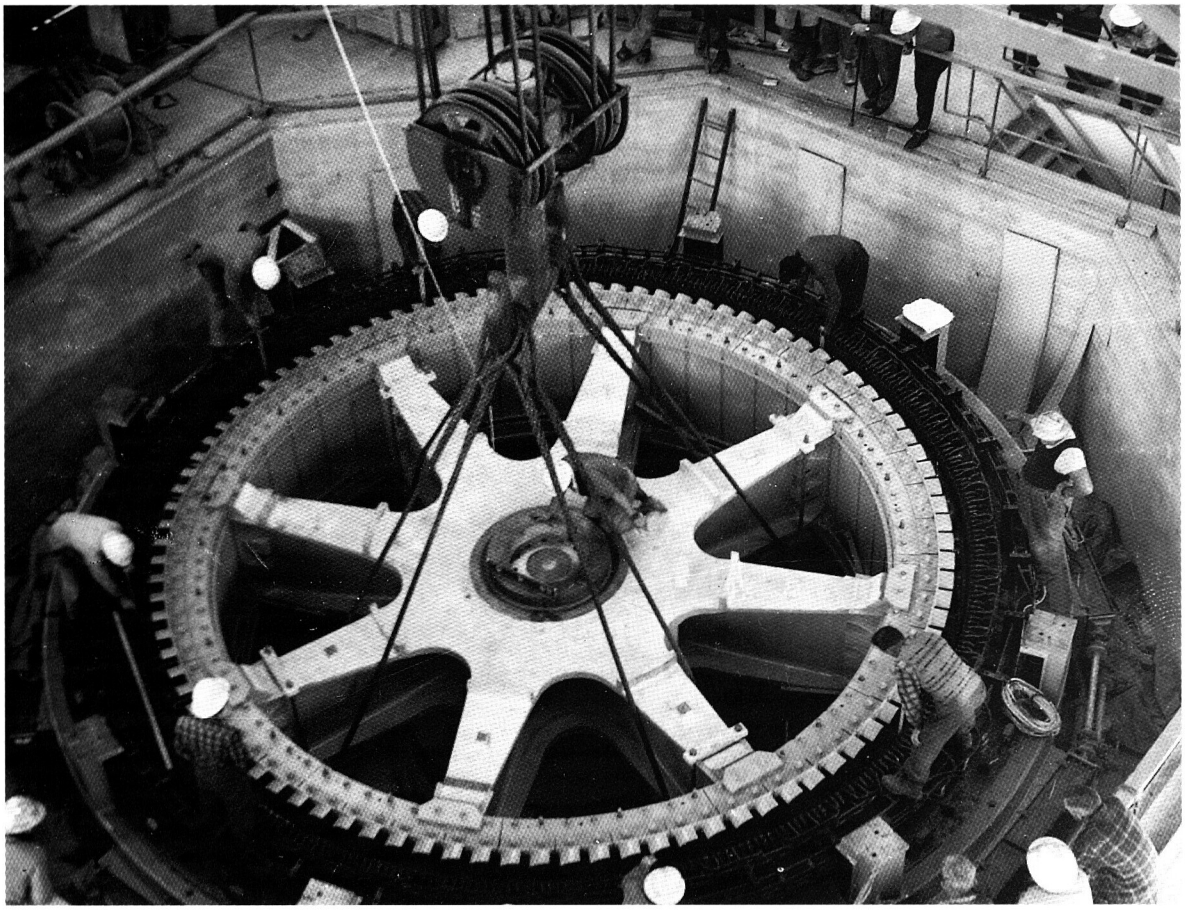


This aerial view of Waipapa taken in February 1961 shows the nearly complete powerhouse at centre right, the earth dam in the middle and the diversion channel and spillway to the left.



Above: Ohakuri's four 28 MW generators in the turbine hall.

Below: The No. 1 generator rotor is lowered into its stator at Ohakuri in April 1960.

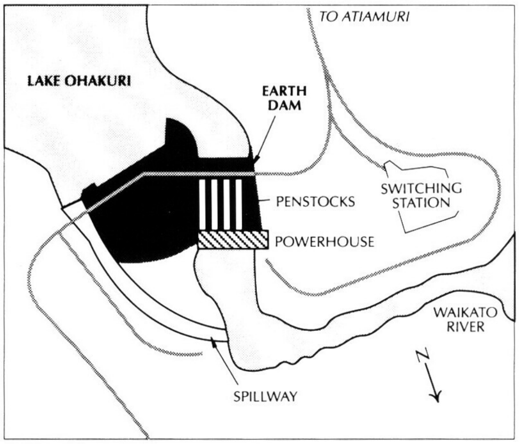


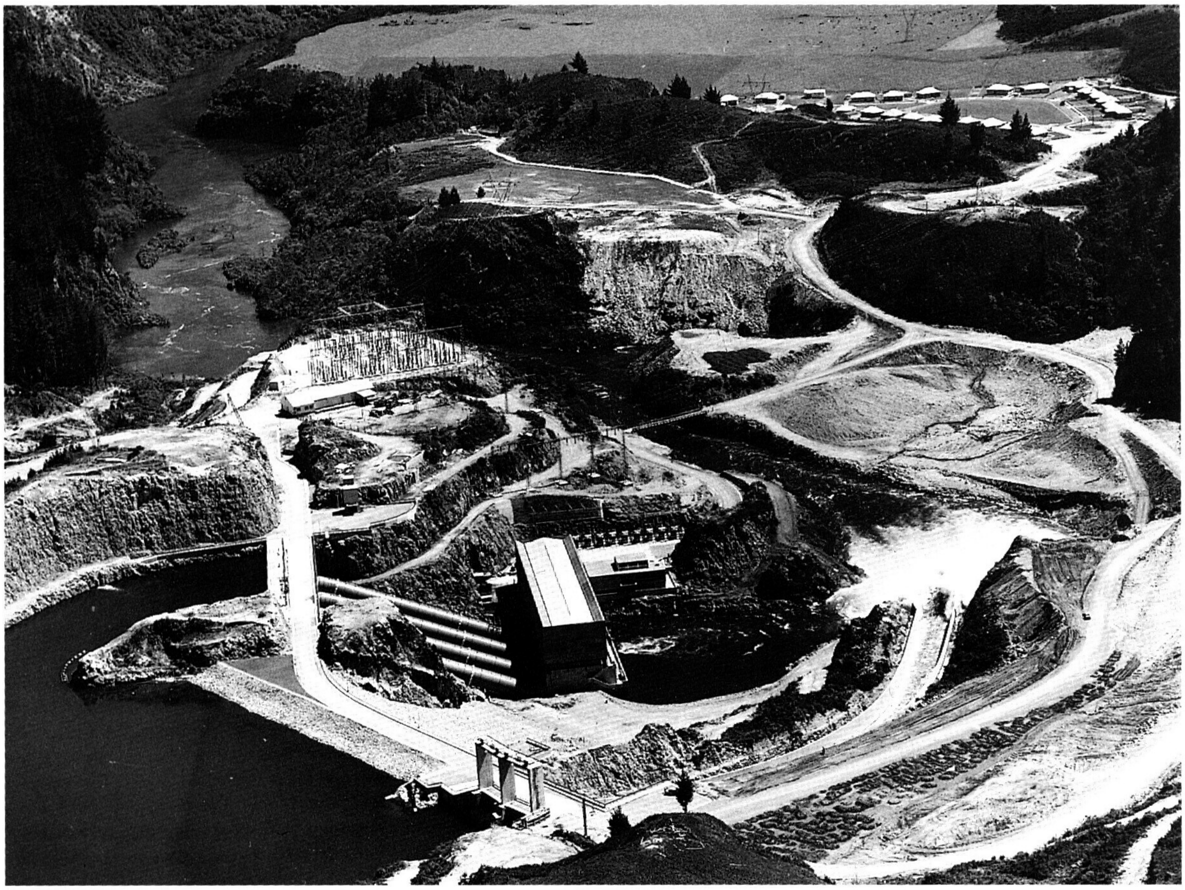
Ohakuri

At Ohakuri the Waikato River runs into a deep gorge after flowing through a wide basin.[17] Because it was initially thought that this site would be the next to be developed after Karapiro, investigations, which included careful scrutiny of foundation conditions, were begun as early as 1939 and continued until 1941. Further investigations began in 1949 and were completed by 1953. After Goosman had initially allotted its design to overseas consultants, this task was in the end given to the Ministry of Works.

The foundations were yet again problematic, and the concrete dam proposed originally had to be replaced by a large earth dam of 400,000 cubic yards with concrete spillway and intake structures. The scheme (with three generators) was approved in November 1955, and work began on

Ohakuri: Constructed 1956–61. Head 115 feet. It comprises a gravity dam, 226 feet long and 59 feet high, and an earth dam, 266 feet long and 161 feet high. Four turbines drive 28 MW generators to produce a total capacity of 112 MW. Lake Ohakuri, at more than 5 square miles, is the largest artificial lake in the North Island.





At Ohakuri the Waikato River flows into a deep gorge The difficult foundations led to the adoption of a largely earth dam, with a small concrete intake section on the far side between the rock outcrop and the side of the gorge, and on the near side a concrete spillway, which is here shown in use.

excavations in May 1956 and on the concrete-lined diversion tunnel, which was 1,350 feet long and 25 feet in diameter, in July. Excavation work for the intake structure and powerhouse was also begun. The river was diverted in October 1958, and the riverbed between the two coffer dams was dewatered. The bed was excavated down to solid rock, and pumice breccia was compacted for the earth dam's impervious core. The spillway is an open concrete channel sweeping around the right-hand side of the dam.

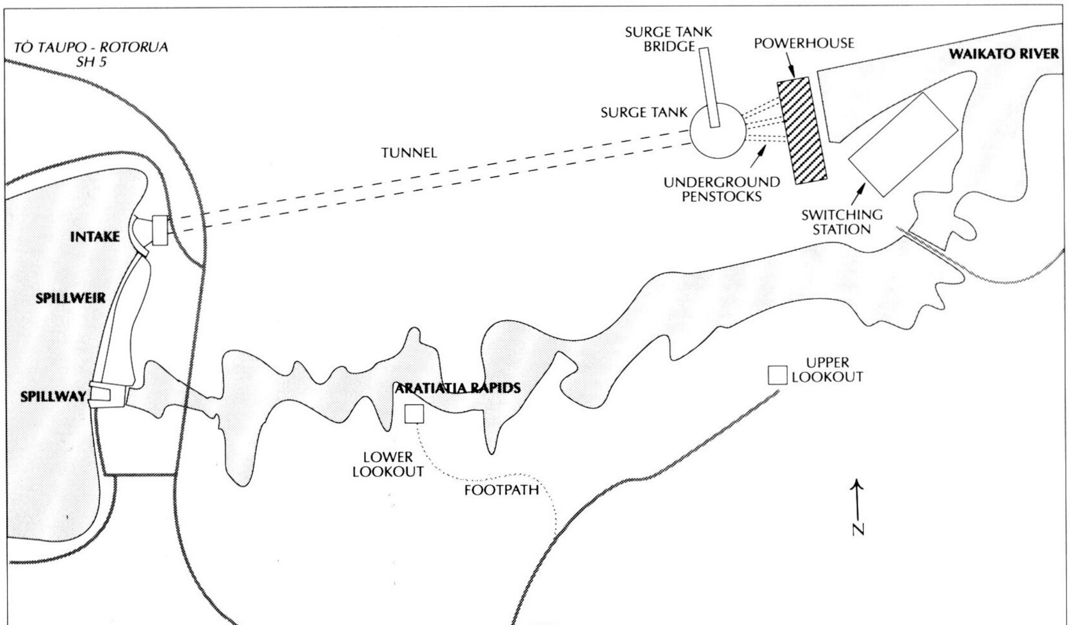
A fourth generator for the station was approved in 1958 as a result of Watt's White Paper. Activity reached a peak in 1959 when some 600 men were employed on the project and good progress was made. In mid-January 1961 the diversion tunnel sluice gate was closed and the large lake began to fill, some two months ahead of schedule. Two-thirds of the renowned Orakei Korako geothermal field, including a number of geysers, and some farm land were submerged as a result. The first two generators were commissioned that month, and power was supplied from 31 January 1961.

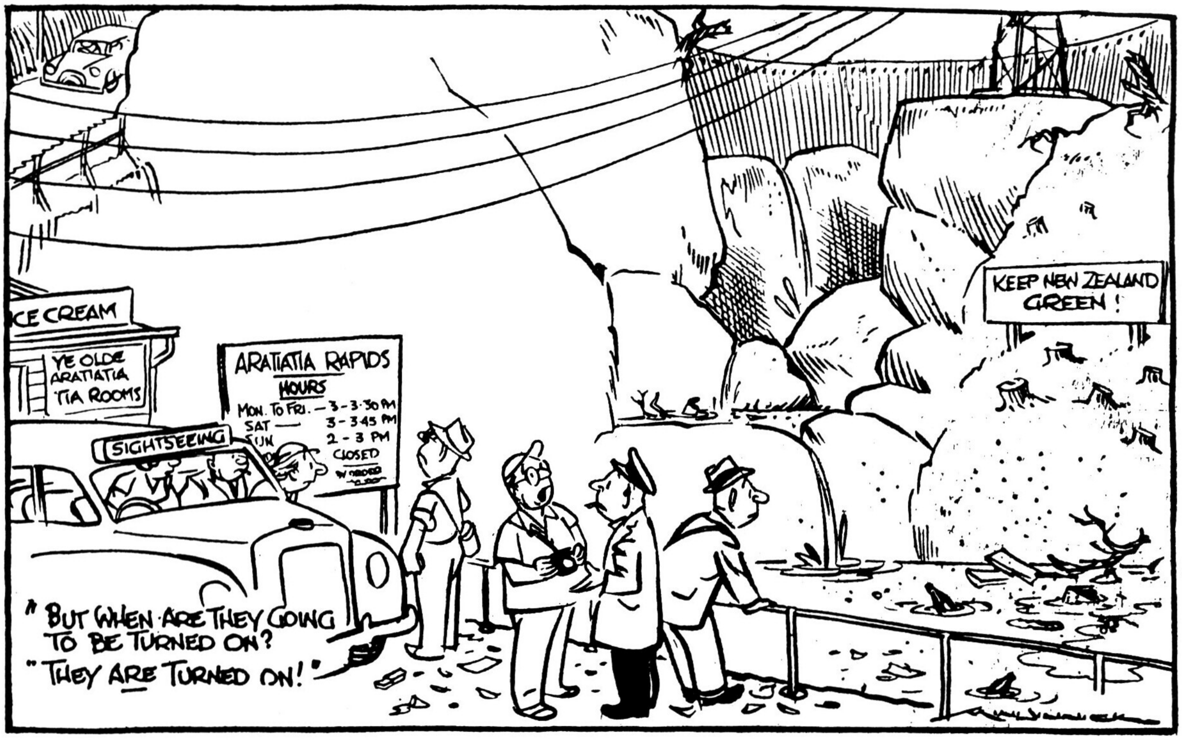
Aratiatia

The possibility that the Aratiatia Rapids and the Huka Falls might be developed gave rise to considerable environmental concern. The rapids, which dropped 93 feet within half a mile, were an obvious candidate for harnessing. Hancock had described the Aratiatia Rapids in 1904 as 'at once the most beautiful and most valuable power-location on the river'.[18] The potential of the Huka Falls had been recognised from the 1890s, and they had received considerable attention in Hay's report of 1904. By the 1940s the separate and partial development of Aratiatia was the most likely option, but Kissel also contemplated a high dam at Aratiatia. This would have flooded most of the existing road, drowned the Huka Falls, had a profound effect on Geyser Valley and produced a large lake extending back to Lake Taupo. Another less ambitious possibility involved a weir at the top of the Huka Falls leading to a powerhouse at the bottom. In the event, the discovery in 1954 of subsurface thermal activity at the falls made their development impossible.

Investigations of Aratiatia began in 1950 and

Aratiatia: Constructed 1959–64. Head 110 feet. A circular reinforced-concrete tunnel, 30 feet in diameter and 1,210 feet long, takes water from a low weir to a large surge chamber, 120 feet in diameter and 55 feet deep, and thence to the powerhouse. Three turbines drive 30 MW generators for a total capacity of 90 MW.





THE MARCH OF PROGRESS

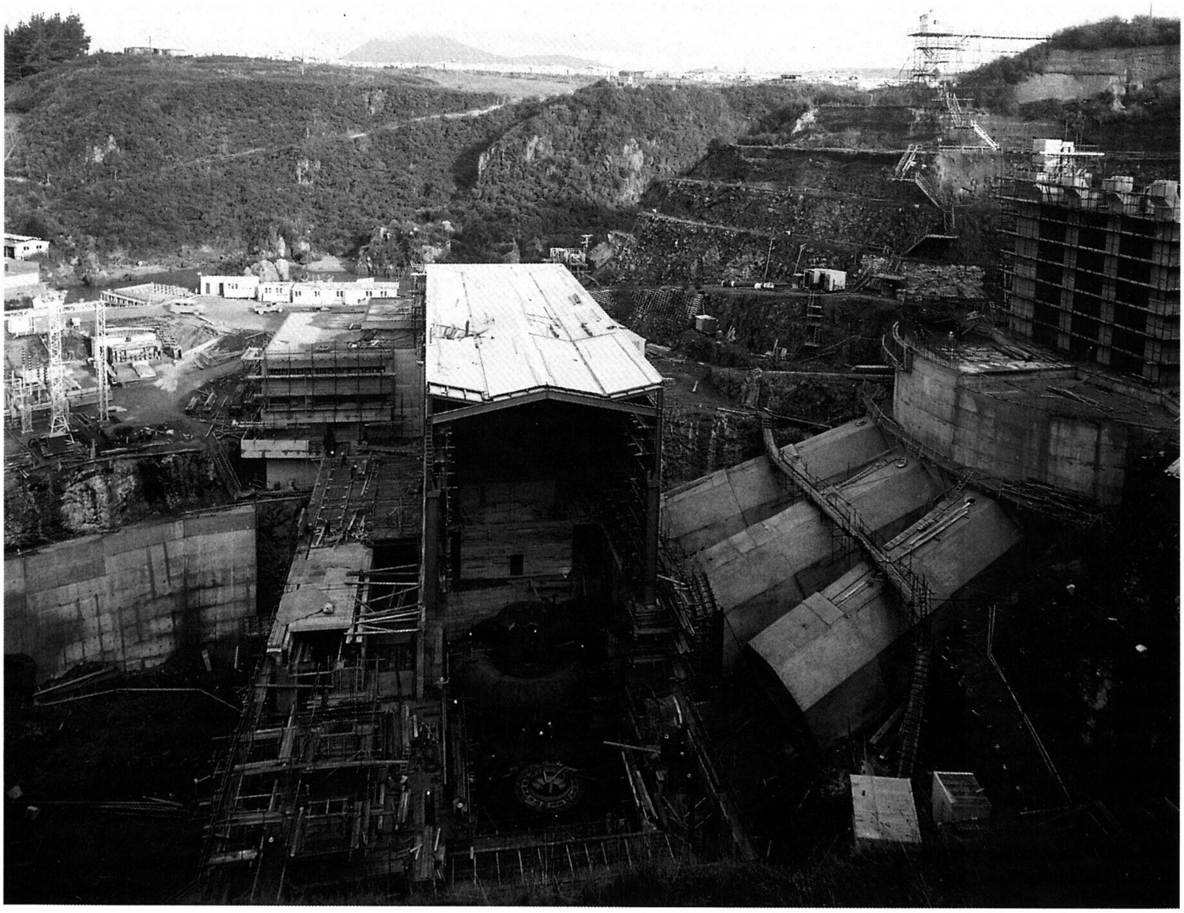
There was much concern that the Aratiatia Rapids on the Waikato River should be preserved as far as possible, and the power station was designed with this in mind. The proposal was to allow water down the rapids at specified times. There was considerable scepticism about what this might mean.
Gordon Minhinnick, *NZ Herald*, 22 August 1958

were undertaken in earnest in 1953–54, subject to the Minister's public statement that 'ways and means of preserving, and if possible improving, the beauty of the falls are being carefully examined'.[19]

In 1957 the Power Planning Committee described the site as the one remaining clearly economic source of power on the river. With Aratiatia complete, some 89 per cent of the total head available from Lake Taupo to the sea would be used. The committee hoped that the station would be in service by 1964.

The project was approved in September 1959 as part of Labour's emphasis on further developing North Island hydro-electric resources. In November conservation groups met with Watt to discuss the future of the rapids and, more generally, the implications of public works in scenic areas. Given that the rapids had to be utilised, the designers attempted to minimise the environmental impact of the scheme. Aratiatia has a weir rather than a dam, and depends more on the steep natural fall of the river than on storage. The major control over the flow of water was to be exercised at the Taupo control works. The rapids themselves were to remain untouched. From a concrete intake structure the water travels along a long concrete-lined tunnel into a huge surge chamber, and down to a powerhouse, sited unobtrusively near the base of the rapids. In view of the projected diversion of water into Lake Taupo from the Tongariro development, it was decided to install a third unit.

Work began in September 1959. More than half the work-force was accommodated in a village established at the site, while the remainder commuted from Atiamuri and Taupo. On 13 August 1960 the river was diverted around the top of the rapids and into an open channel. By the end of the year half of the tunnel had been driven. Construction occurred at each end of the rapids without roads being built alongside them. About a quarter of the tunnel was dug as an open trench and then backfilled. Nearly a million cubic yards of material was excavated for the surge chamber and powerhouse. The surge chamber was built by the technique of 'slipforming', in which the walls were progressively concreted upwards, in 80 hours of non-stop work. This method had not



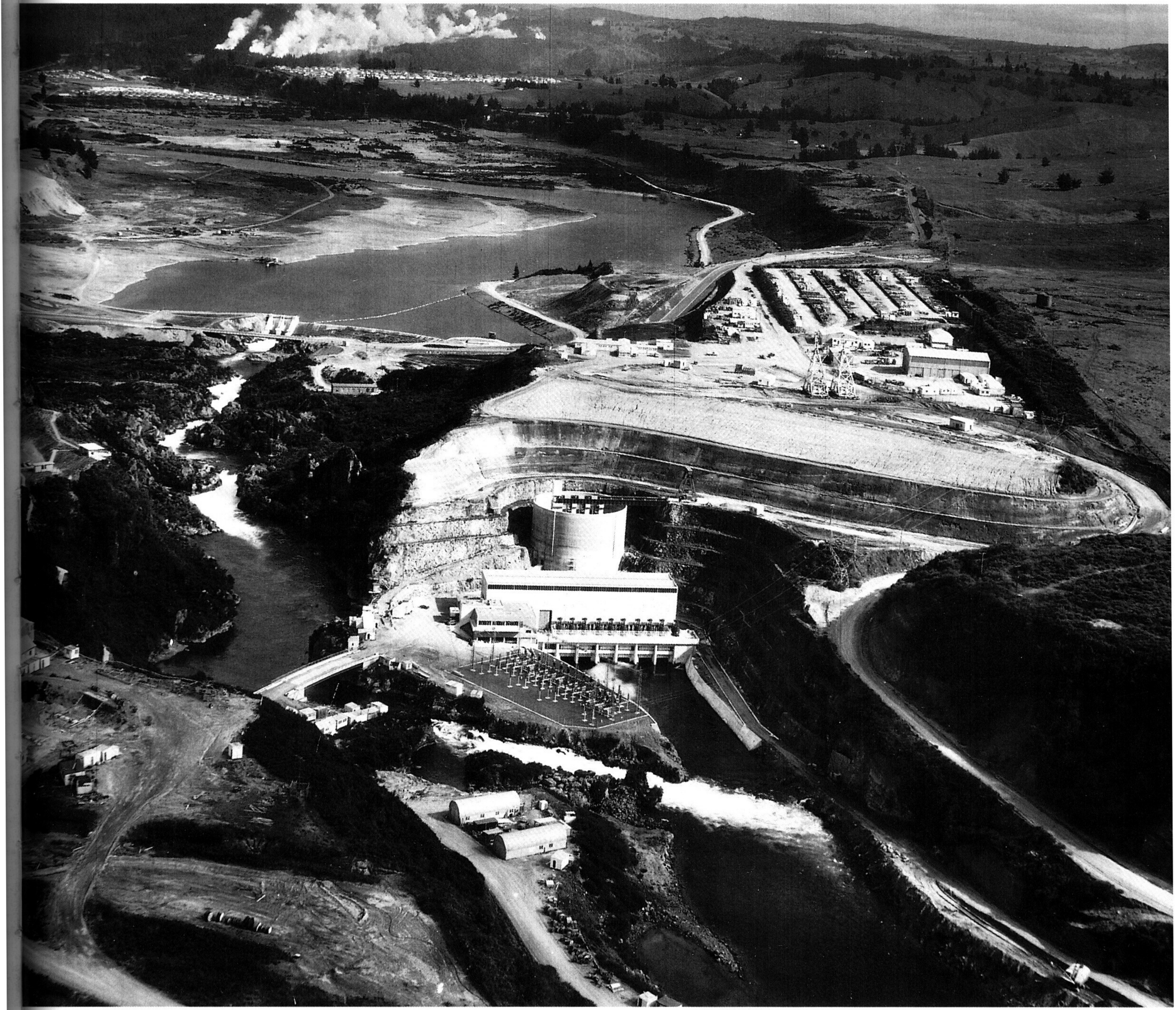
been used before in New Zealand and aroused much interest.

A massive landscaping programme using more than two million native plants and several hundred thousand trees was undertaken to minimise the visual impact of the scheme. Access tracks were formed and public viewing platforms built. The lake was filled on 6 March 1964, and the first unit began producing power that month. The second machine came into use in April and the third in May. The weir raised the level of the river some sixteen feet, the lake stretching back six miles to the Huka Falls, and raised the water level at the bottom of the falls by about four feet. Twice daily, at 10 a.m. and 2.30 p.m., the spillway gates are opened and normal flow is restored to the rapids for an hour and a half.

The completion of Aratiatia marked the end of the era of continuous development of the Waikato, which had begun with the construction of Karapiro more than two decades previously.

Above: The Aratiatia powerhouse was set into the hill at the base of the rapids, with the three turbines being fed by short splayed concrete penstocks from the surge chamber, as shown here. Water is taken from the lake through a tunnel to the powerhouse. The rock formation of the rapids has been left intact.

Opposite: Looking back up the Aratiatia Rapids past the power station. The massive concrete surge chamber is clearly shown, as are the control works and weir above the rapids. Behind the lake the Wairakei village and steamfield can be seen. A very extensive planting programme rapidly covered the scars of construction. The control gates are opened twice daily for an hour and a half, restoring the normal flow of the rapids seen in this photograph. The public viewing area is at the left of the rapids.
Whites Aviation



CHAPTER EIGHT

The Cook Strait Cable

BEFORE DESCRIBING the creation of the inter-island link across Cook Strait, we will look first at the emergence of an interconnected network and the establishment of a system-control centre in each island, for it was this process that led to the demand for a single truly national system.

The interconnected network and system control

In its early stages power planning was concerned with building power stations for local supply. The state-provided transmission system had its beginnings in the transmission of power at 66 kV from Lake Coleridge to Christchurch in 1914. By 1919 Horahora power was being taken north by a 50 kV line to Hamilton and beyond. The first 110 kV line was built in 1924 to transmit Mangahao power to southern parts of the North Island.

It soon became apparent that major hydro-electric developments were justifiable only in terms of electricity supply to the whole of each island. By 1934 the North Island had a single interconnected system based on 110 kV and 50 kV lines. Two separate systems, based on 110 kV and 66 kV, developed for the Nelson-Marlborough region and for the remainder of the South Island.

Arapuni and Karapiro became the main sources of supply to the northern half of the North Island, with Waikaremoana and Mangahao serving the island's southern half. Arapuni was connected by two 110 kV lines southwards to Bunnythorpe in the Manawatu, but this was more to serve the area in between than to provide mutual support between the north and south of the island.

This interconnection did, however, help to focus attention on the need for unified control of all major power stations and a strengthening of the network. The latter was not only to cope with increasing loads but also to allow flexibility in the loading of individual power stations. Thus, for example, variable inflows to Waikaremoana and Lake Taupo could be offset by energy transfers between these two areas. The controlling of Lake Taupo in 1941 and Waikaremoana in 1946 also promoted the functioning of the network.

After visiting the United States and Canada to study 220 kV lines, a senior departmental engineer recommended strongly that this voltage be used here, and it was adopted following the large-scale development of the Waikato River. Transmission at this voltage was increasingly common in a number of other countries by this time. Whakamaru became the central substation for the emerging 220 kV network.

In the late 1940s routes were surveyed from Whakamaru 120 miles north to Otahuhu, in Auckland, and 140 miles south to Bunnythorpe. It was also necessary to interlink the Waikato stations at 110 kV and run other 110 kV lines from Bunnythorpe to Wanganui and from Henderson to near Whangarei.

From 1949, towers were erected and lines strung, and major substations were built at Otahuhu, Bunnythorpe and Haywards (near Wellington) to connect with the lighter 110 kV network. Two separate circuits were provided for security of supply. Although many other 220 kV lines have been built subsequently, this original 220 kV line continues to provide the primary arterial route. It was completed in 1953.

In the South Island, power from Coleridge had been taken from Hororata to supply centres as far south as Oamaru. From 1935 twin 110 kV lines were built to convey power from Waitaki north to Hororata and south to Dunedin, where they linked up with Waipori and the 66 kV Invercargill system supplied from Monowai. In 1939, a 66 kV line was put through to the West Coast via Arthur's Pass. A separate system for the Nelson-Marlborough region was developed around the Cobb River station after the Second World War.

With the construction of Roxburgh in the 1950s, a 220 kV line was run 230 miles from there to Islington in Christchurch in 1956, while 110 kV lines from Roxburgh gave additional support to Dunedin and Invercargill. Only a single 220 kV line of such length could be justified at that time, in spite of the risk of supply to Christchurch being interrupted.

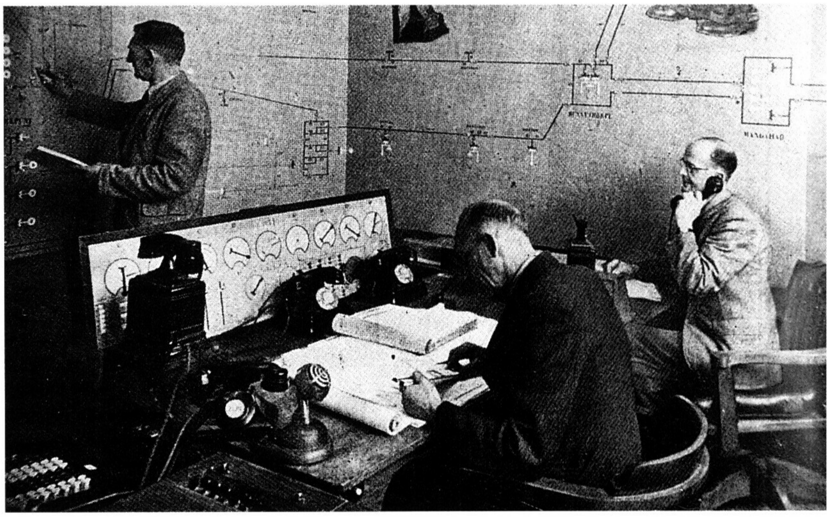
The Nelson-Marlborough region was first linked into the wider South Island system in 1956 by a 110 kV line between Stoke (near Nelson) and Inangahua, and then in 1959 by the main Islington–Kikiwa 220 kV line, which extended the main system to the top of the South Island. Further building of power stations in the Waitaki basin and at Manapouri in the far south in the 1960s resulted in the construction of multiple 220 kV lines all the way from Manapouri to Stoke.

In order to maintain a dependable supply to consumers, the generators must be held at the speed and voltage required despite fluctuations in load, and any necessary switching of transmission circuits made. These are the tasks of 'system control'.

With only one or two sources of power, and only a limited amount of switching to be carried out, it was possible to control these functions at a single power station, or on a shared basis with stations taking turns as 'control' station. The Waikato River development, together with the planned 220 kV system, made it necessary to create a separate system-control group.

The first system-control centre was set up in 1939 at the Hamilton district headquarters at Claudelands, and soon proved its worth. A North Island control centre was established in 1961 close to the Whakamaru switching station at the hub of the 220 kV network.

Until the late 1940s, South Island system control was shared between the Coleridge, Waitaki and Waipori power stations. The post-war plans for the development of the Clutha River led to the establishment of a small system-control centre at Addington, which was later moved to the Islington 220 kV substation following its construction in 1956. The South Island centre at Islington performs similar functions to that at Whakamaru but, given that all power generated in the South Island is hydro-electric, the water-management problems are more diverse.



A load dispatch office, as it was then called, was established at Claudelands in Hamilton in 1939 as the first North Island system-control centre. The power network was displayed on the wall diagram to show the status of the system. From here the system operators monitored changes in system loading and ordered the switching in and out of generators to meet fluctuations in demand.

Hydro-electric Power, State Hydro-electric Department, *c.* 1949.

As the network has grown, system operators have carried out an increasingly wide range of tasks. Hydro-electric stations must be run to use their water most efficiently, while the use of supplementary thermal stations must be based on minimising costs. Above all, the system operators must ensure that enough generating plant is held in reserve, already spinning, to meet unexpected contingencies. Switching of the network becomes routine with experience, but during major system disturbances the pressure can be intense. The job calls for a high degree of knowledge and composure on the part of the system controllers.

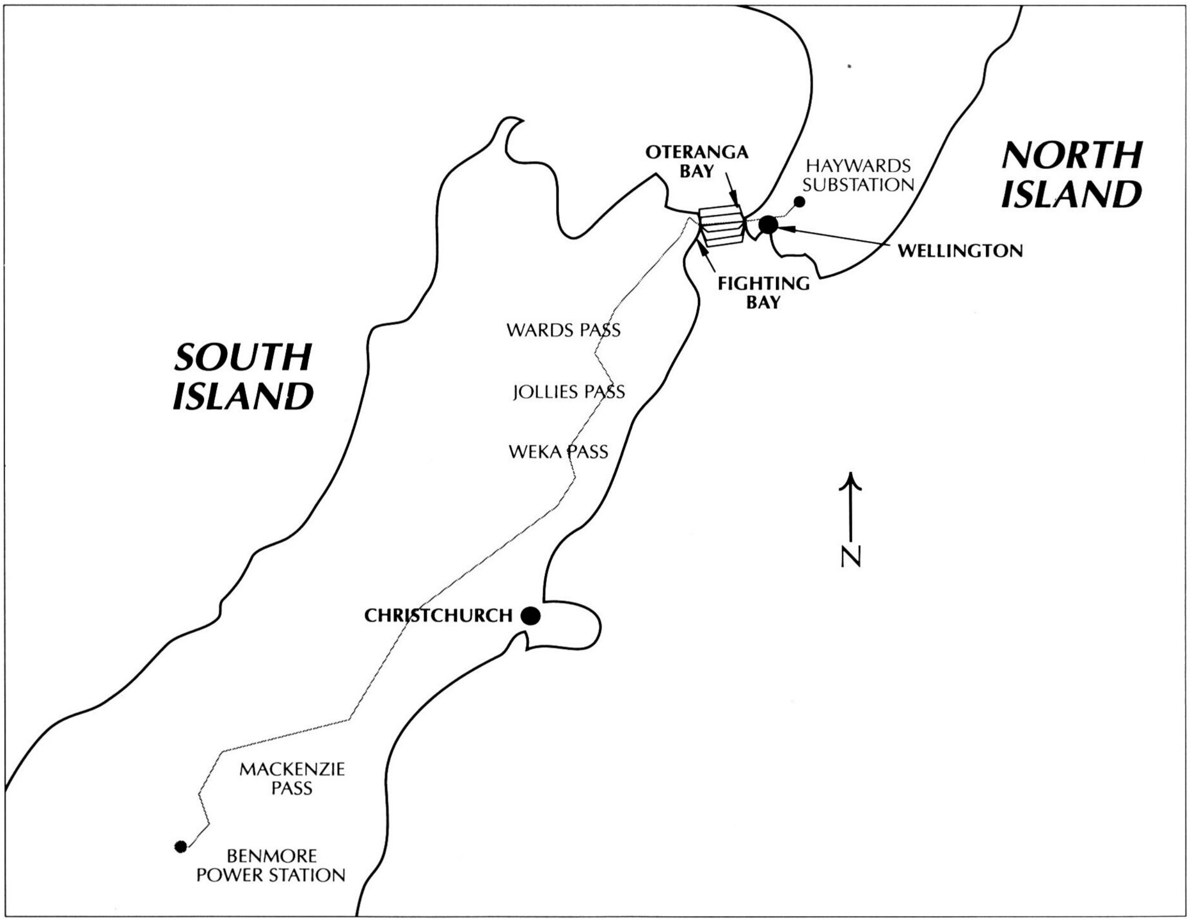
The operation of all major high-voltage plant and equipment is subject to system-control requirements, and its release for maintenance by station or line staff is dependent on a daily assessment of the cost and risk to continuity of supply within the system as a whole. The managers of the control centres rank alongside the managers of major power stations in their contribution to the provision of a safe and reliable power supply.

In 1965 the two islands were linked by the Cook Strait cable. The North and South Island control centres still operate independently, but the daily energy transfers over the Cook Strait cable are determined centrally in Wellington.

The Cook Strait cable

In 1950 M. G. Latta, Chief Engineer of the State Hydro-electric Department, produced a paper on the future supply of power in New Zealand.[1] This was remarkable both as a far-sighted general survey and because it put on the agenda a daring technological advance and a project which was extremely difficult by world standards — the Cook Strait cable (otherwise known as the Benmore–Haywards high-voltage DC link). It was the world's third submarine DC link when it was commissioned eleven years after the first, at Gotland, Sweden. The inter-island link, engineered entirely by the Electricity Department, was the largest and most ambitious such project of its time in the Western world.

Latta argued in 1950 that the effective limit of hydro-electric capacity in the North Island would be reached when the load was about two and a half times its present level. From 1925 to 1949 the average annual rate of increase in the number of units generated in the North Island was 9.7 per cent, a figure similar to that in other countries. Assuming that the best guide to the future was the long-term past trend, Latta made assertions that lay at the heart of New Zealand power planning: load would continue to grow, and the North Island's hydro-electric capacity would be fully developed in the foreseeable future. There was no sign in other countries of a levelling-off in demand. The North Island's hydro-electric resources would be exhausted as early as 1959 if the annual growth rate was 10 per cent, and a decade later if it was 5 per cent. Then what? One by one he dismissed other alternatives. New Zealand's coal supply was too small and too expensive; oil-fired stations were expensive and relied on imported fuel; the potential of nuclear stations had been exaggerated; gas-turbine stations



Matthew Garnet (Bill) Latta was born in Invercargill in 1903 and educated at Canterbury University College.[2] He joined the Hamilton office of the Hydro-electric Branch of the Public Works Department in 1923. After gaining substantial overseas experience in the United States, Britain and Sweden, he joined head office on his return to New Zealand in 1929 and remained there for the rest of his career. From 1941 he was responsible for the co-ordination and supervision of all departmental design work, including the 220 kV transmission system. He was appointed Chief Engineer in 1948, and oversaw the crucial post-war expansion of the generation and transmission network. In 1950 Latta delivered his key paper on the need for the Cook Strait cable to the supply authorities conference. This project, his brainchild, was approved in 1961, two years before his retirement, and commissioned in 1965. In 1966 Latta was awarded the CBE for his contribution to electrical engineering. He died in May 1971.

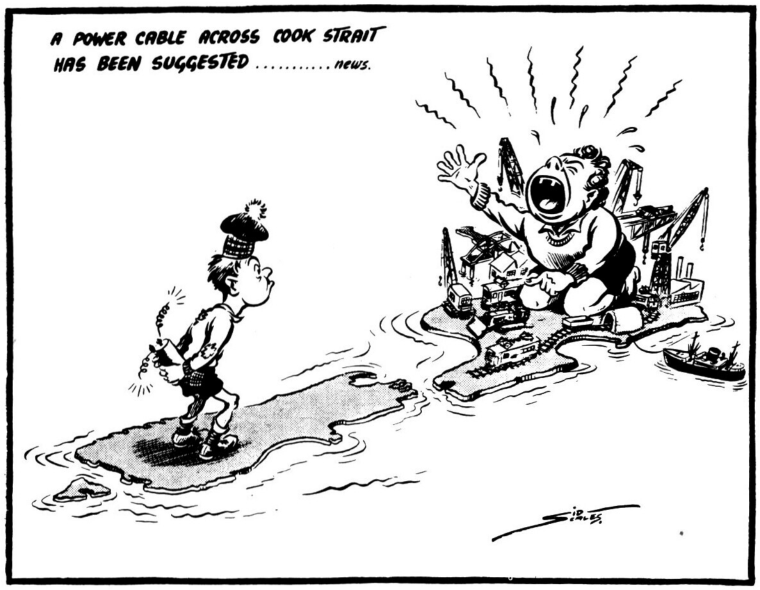
were not suitable for base load; geothermal energy was very much an unknown quantity; tidal energy was of little significance because the tidal range was small; wind was not feasible as a reliable source for large power systems.

Were it not for the existence of Cook Strait, Latta argued, South Island hydro-electric stations could supply the southern half of the North Island and ensure that the country's load was met for many years to come. A single generating system would have other advantages. The South Island lakes offered a large potential for storing water, and the peak river flows in the two islands were complementary. In the North maximum flows came in winter, but there was little long-term storage capacity. In the South Island high-country snow and ice melt created maximum flows in late spring and summer in rivers such as the Waitaki, which offered huge storage potential. A cable across Cook Strait and the development of this storage capacity would allow the transfer of considerable energy to the North Island in winter.

Latta believed that the technology of high-voltage DC transmission that would be needed to overcome the barrier would soon be available. He referred to the undersea cable link between mainland Sweden and Gotland, which was to transmit 20 MW DC at 100 kV over 60 miles. The best way to transmit large amounts of power over long distances, particularly when submarine transmission was involved, was by high-voltage DC. But DC had to be converted from and to AC. This conversion of large currents had been made possible by the development in the 1930s of the mercury-arc rectifier, and DC transmission had been pursued in Sweden, West Germany and the Soviet Union. The problem was that in the early 1950s, conversion equipment for large amounts of power at very high voltages was still not very reliable.

This was not the first time that the possibility of getting power across Cook Strait had been raised. It had been mentioned as early as the 1920s. Kissel had been unenthusiastic when the issue came up again in 1945, because the available sources of power were in the southern half of the South Island, making transmission distances too great. Davenport, however, was more receptive to the idea. The survey ship *Lachlan* had by August 1950 produced a series of soundings of the strait's bottom that indicated that it might not be as full of steep undersea hills and valleys as had been feared.

In 1950 the government invited to New Zealand the Chief Engineer of British Insulated Callender's Cables Ltd (BICC), a company with unparalleled experience in both manufacturing and laying submarine cables. He reported in July


A POWER CABLE ACROSS COOK STRAIT HAS BEEN SUGGESTED ....news.

"MUM — HE'S GOT THE BATTERY!"

The prospect of a Cook Strait cable stirred strong feelings in the South Island.
Sid Scales, *Otago Daily Times*, 17 July 1952

1951 that the scheme was possible but extremely difficult, and BICC proposed that it should investigate the project's feasibility further, including manufacture and tests of a trial length of cable. This was not given the go-ahead.

The timing of Latta's report had been very awkward politically. South Island consumers were acutely aware that they would suffer power shortages until Roxburgh was commissioned. Indeed, Davenport told one South Island conference that the government would not run a cable across Cook Strait 'to take power to greedy neighbours in the north'. Goosman also told Parliament that it would never happen, if only because of the power losses in transmission. For some years the idea of the cable faded from view as attention was directed towards Meremere and geothermal development. But Latta did not give up. He several times urged unsuccessfully that BICC be given its contract, and kept careful track of overseas developments. The Swedes had now successfully laid their link to Gotland, and other schemes were in progress.

Latta went overseas in 1955 to investigate gas-turbine plants and managed to keep up with submarine-cable developments by visiting various countries. On his return he reiterated his previous arguments and urged that the proposal be investigated by BICC. The crucial factor in many respects was not so much the cable itself, which could be laid quickly, as a large new hydro-electric power station on the Waitaki (Benmore), which would take a long time to build.

Cabinet was persuaded, and in early 1956 BICC at last got its contract to report on the feasibility of the scheme. The contract included the design, manufacture and testing of samples of cable, and extensive surveys of the seabed and tidal currents, and of shore conditions on the proposed routes.

The government now had to tell South Islanders still suffering severe shortages that the cable was under consideration after all. It argued that Roxburgh was about to solve the South Island's problems for many years to come. The Benmore proposal, announced at the same time, did not mollify opinion, even though it meant jobs. For some South Islanders the cable was a symbolic drain on resources; for others it was the 'theft' of cheap power that had the potential to draw industry and population south again.

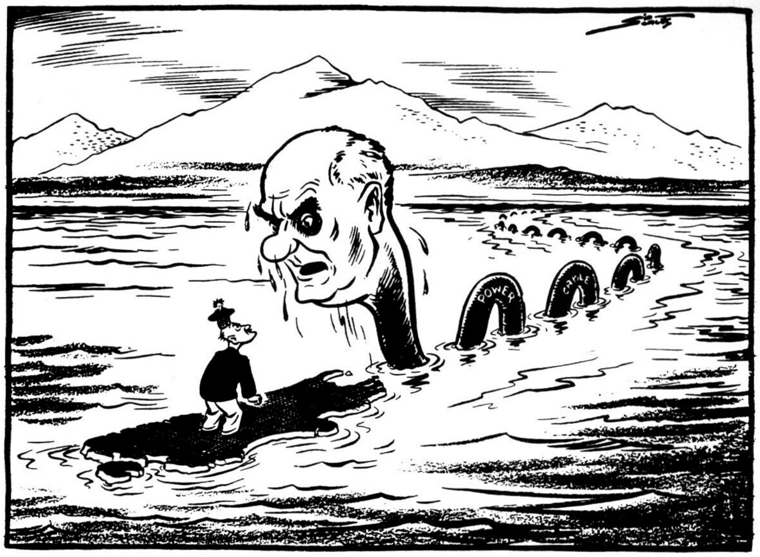
For reasons of cost the State Hydro-electric Department was very anxious to use the 24½-mile route from the reasonably sheltered and sandy-bottomed Fighting Bay, north-east of Blenheim in the outer Marlborough Sounds, to the exposed Oteranga Bay, on Wellington's rugged southern coastline. A longer alternative route might have an easier sea floor but would be very much more expensive. AC transmission remained an option in theory, but would be at least 30 per cent more expensive than DC, and there seemed to be growing evidence from the Gotland experience that the Swedish ASEA company could provide reliable mercury-arc rectifiers.

In December 1956 BICC reported that the project was 'thoroughly practicable'. They recommended the Fighting Bay–Oteranga Bay route, and DC transmission of 600 MW over two cables with a third as a spare. This was the scheme that was eventually adopted after much debate. Assurances were given that it would be possible to make repairs if faults developed. BICC also recommended testing of the cable for up to two years.

Many remained sceptical, including some Post Office and Ministry of Works engineers, and opposition to the cable emerged. As early as August 1956 the Commissioner of Works, F. M. H. Hanson, stated publicly that the need for an inter-island link was not urgent because of the prospect of geothermal steam becoming available. Davenport and Latta were probably less convinced that substantial geothermal generation was possible. In July 1956 Hanson and his Engineer-in-Chief had been appointed to the Combined Committee on the New Zealand Electric Power Supply. They would go no further than approve the cable in principle, with testing to continue, arguing that the only information received had come from the likely contractor. They had two major objections: that BICC might have underestimated the cost and time involved in a major repair, and more importantly, that the proposed Oteranga Bay route ignored many years of Post Office experience that indicated that serious chafing on rock would probably be caused by tidal currents. Davenport insisted that the cable would move far less than the Post Office cables because of its armouring and its greater ratio of weight to diameter. The Combined Committee on the New Zealand Electric Power Supply reported in March 1957, recommending approval of Benmore as soon as possible and approval in principle for the inter-island link.

The criticisms made the State Hydro-electric Department consider a route ending at Lyall Bay, as used by the Post Office. This route was nearly twice as long as that to Oteranga Bay, much more expensive, and would raise problems with transmission from Lyall Bay to Haywards. The debate delayed Cabinet agreement to the manufacture of cable and the laying of trial lengths until August 1957. (Two half-mile lengths of cable were laid off Oteranga Bay in 1958.) Meanwhile in October 1957 the Benmore project (with two generating units) was approved. Later that year Labour became the government and, as we have seen, the political balance shifted away from the State Hydro-electric Department towards the Ministry of Works as Hugh Watt took both portfolios. Because Labour favoured the development of North Island hydro-electricity, and because of economic constraints and interdepartmental conflict, Watt's August 1958 White Paper announced the deferral of the cable for a year.

A lack of the resources needed for data collection meant that there continued to be uncertainty about currents on the seafloor and their effect on the cable. In November 1958 the British firm of Preece, Cardew and Rider was asked for an independent report. Meanwhile Captain O. R. Bates, seconded from the British General Post Office and master of a cable-laying ship, was commissioned to report. However, the weather in Cook Strait was atrocious for most of his visit in May 1959, and he was unable to measure the currents adequately. His report was based largely on his wide experience elsewhere. Bates preferred a route from Cloudy Bay (which was closer to Blenheim and would allow the ship to approach much closer to the beach) to Fitzroy Bay (between Pencarrow and Baring Heads). Because of planned airport development, Lyall Bay was no longer an option.



THE COOK STRAIT MONSTER

Stan Goosman, Minister of Works and Electricity, is here represented as a Cook Strait cable sea-monster threatening the South Island.

Sid Scales, *Otago Daily Times*, 9 March 1956

Preece, Cardew and Rider's report, a very thorough and detailed survey, was received in October 1959. It argued that the scheme recommended by the 1957 Combined Committee was the 'simplest and most economic scheme' which was 'practicable to construct and will be reliable in operation'.[3] The economic advantages of Gotland's DC system emphatically outweighed its lower operating reliability compared with AC.

The report favoured the short route while acknowledging that further investigations were needed and suggesting that tidal patterns and the sea-floor conditions for both routes should be looked at. The route suggested by Bates would cost more than twice as much, allowing for additional electrical losses. However, in view of the deteriorating economic situation, the Labour Cabinet in March 1960 accepted the Ministry of Works' recommendation that a decision be postponed for a year.

In the early months of 1960, however, the lengths of cable laid nearly two years before were recovered and found to be in excellent condition, while further underwater photography reduced the fear of rock formations on the seabed. At a meeting of power planners in May, Latta argued that all the reports and evidence indicated that the short route was practicable. But Watt was still chairman of the Power Planning Committee, and Ministry of Works and Treasury representatives outnumbered those from the Electricity Department. The committee merely agreed that it could do nothing until the cable issue was resolved.

Before the end of the year, however, National was returned to office and Goosman, whose sympathies were more with the Electricity Department, was back as Minister. He reconstituted the Power Planning Committee and made Davenport its chairman, and also made it clear that it was free to recommend the cable if it thought fit. To demonstrate the cable's durability, Goosman obtained a 90 lb sample, staggered across the floor of the debating chamber and deposited it on the table of the House. But the cable still had many political opponents, and Goosman, who remained a little uncertain, asked Hanson for an independent report on the project.

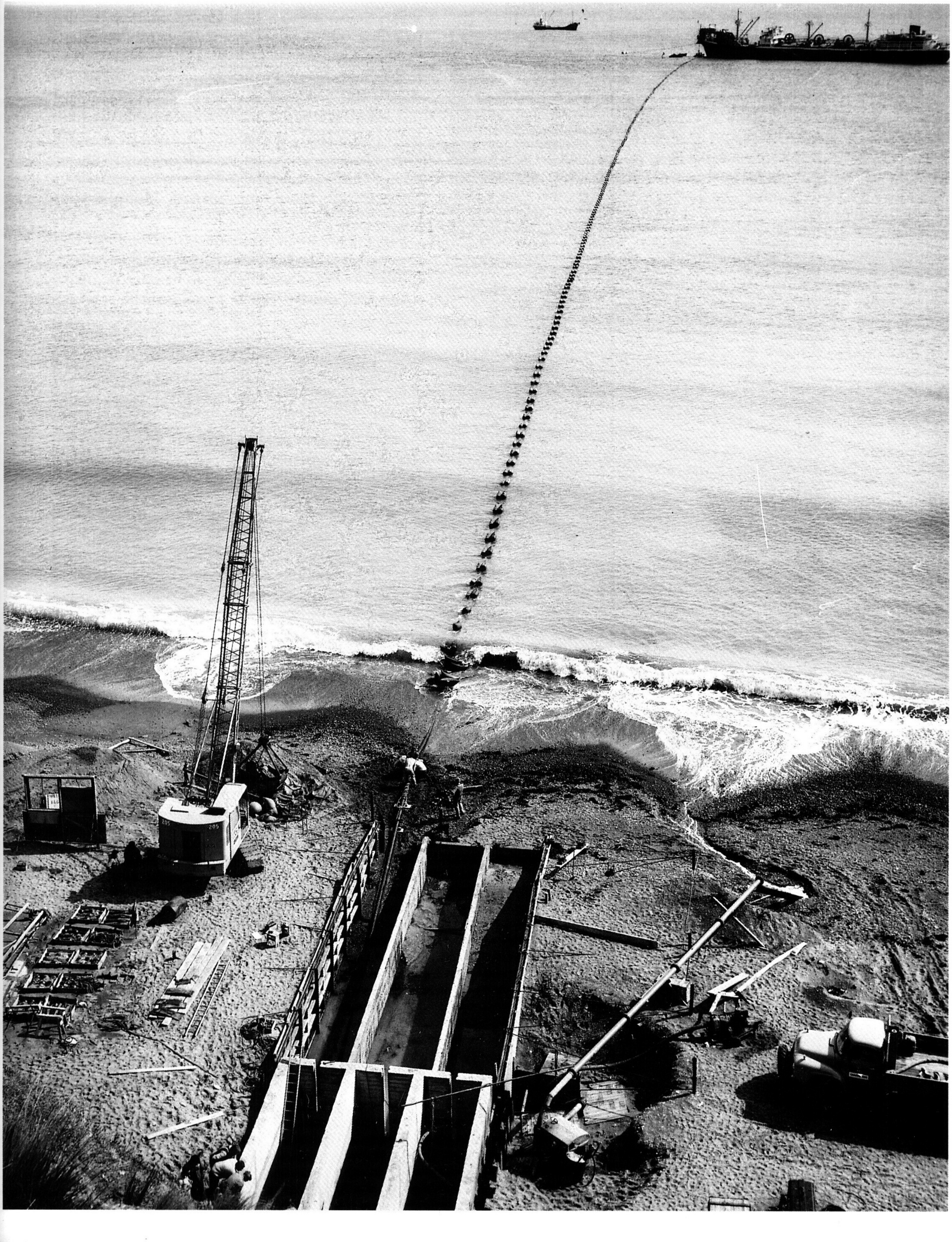
The Power Planning Committee met for two days in January 1961. One of its two Ministry of Works members argued that the cable would actually move more than smaller and lighter ones. The question was not resolved until a BICC team came to New Zealand in February for final discussions on the cable and asserted that they were confident of its success. After an entire day of debate the cable received majority approval. For a time a Ministry of Works minority report seemed possible, but the Commissioner of Works gave up under pressure from Goosman. By now the ministry was less confident about further North Island hydro-electric development and Wairakei no longer looked as promising.

The committee reported on 1 March 1961, asking for approval for the link and the addition of four generating units at Benmore to bring the station up to its full capacity. On 13 March Hanson submitted his report, which supported the committee's recommendations. At the end of March Cabinet approved the laying of the cables and the construction of the high-voltage DC transmission line that would take power 400 miles from Benmore to Haywards, as well as the conversion equipment at both ends of the line and the four additional machines at Benmore. The target date for completion was April 1965. Time was short!

BICC and ASEA rapidly won contracts against little or no opposition. ASEA was to provide the high-voltage DC converter plants at Benmore and Haywards, while BICC was to manufacture three unjointed lengths of more than 25 miles of specially designed cable and lay it as three lines, one being a spare. The voltage between the two cables was 500 kV. The cables were five inches in diameter with a conductor area of 0.8 square inches, paper-insulated and pressurised internally by nitrogen at 425 lb psi to cope with the water pressure at the deepest point (850 feet). Each weighed 1,500 tons; these were the longest and heaviest cables ever manufactured to that time. The cables also had by far the greatest capacity of any submarine cable yet made, and were the first to be gas-pressurised.

The cables were laid in late 1964. The laying was surprisingly quick, not being seriously affected by the notorious Cook Strait weather. The bulk carrier MV *Photinia* was specially converted for laying, fitted with a bow propeller, and provided with the latest precision radio-navigation aids for precise fixing of position. The laying of the first cable began at Oteranga Bay at noon on 12 November. Each cable was coiled in a separate hold, out of which it was drawn over a bow sheave. A 'floating head' was used to land the cable end on the shore from the *Photinia*. Floats supported the cable during this process. After six hours the shore end laying was completed and the ship was able to move out into Cook Strait. The *Photinia* crossed the strait within six hours and reached Fighting Bay at midnight. A further six hours from first light was spent laying the Fighting Bay end. This process was repeated for the other two cables. The second cable was laid after a ten-day delay caused by bad weather, and the third was laid by 13 December. All went well, except that the last cable developed a kink when unexpectedly powerful currents moved the ship. This was only discovered during testing, and after many problems, between March and May 1965 a new section was spliced into the cable to replace the damaged section.

Opposite: Cable laying began at the northern (Oteranga Bay) end in November 1964. Here the first cable is taken ashore from the cable-laying ship, MV *Photinia*, and enters one of the concrete cable-joint pits in the foreground. Between shore and the ship the cable is supported by pairs of inflated plastic floats, which were deflated to drop the cable onto the seabed. On the *Photinia* the large sheaves above the three holds containing the cables can be seen.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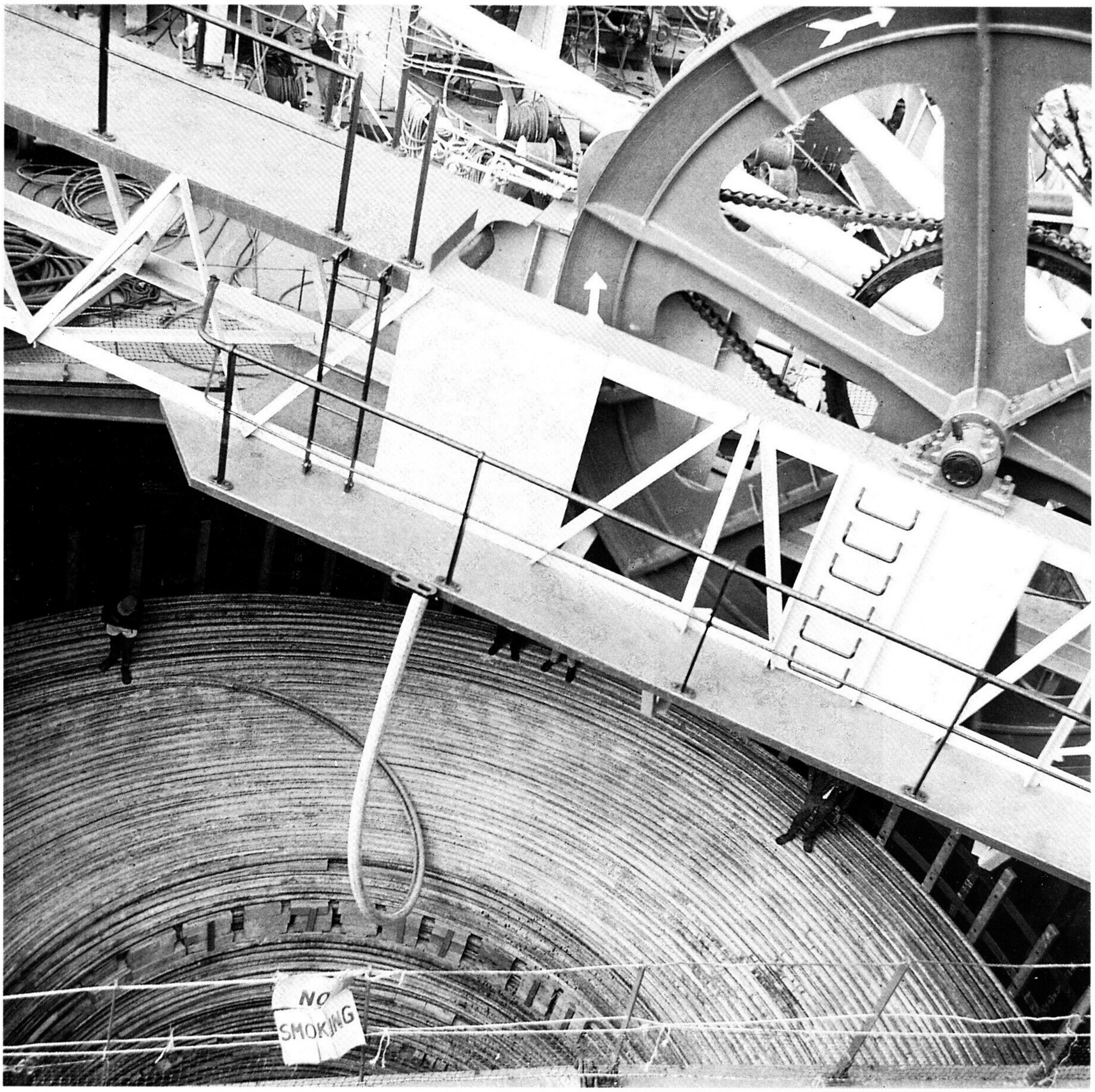
Besides the standard outdoor stations, which step up the generation voltage to 220 kV AC, at Benmore and Haywards it was necessary to install converter stations, each housing 28 special mercury-arc rectifying valves, which convert 110 kV AC to 500 kV DC at Benmore and reverse the process at Haywards. These buildings were air-conditioned for temperature control and to keep the air free of mercury vapour and dust. Cable terminals had also to be built on each side of Cook Strait. The link is bipolar, using two separate cables as conductors of opposite polarity (in this case ±250 kV). In emergency or fault conditions the link can operate at half capacity on one pole using one cable as a conductor, with the earth itself used as the other conductor. This required the design and placing of sea and earth electrodes to provide the connections to earth. The earth electrode is near Benmore, and the sea electrode on the coast near Makara. These were themselves major design achievements, with little previous experience as a guide.

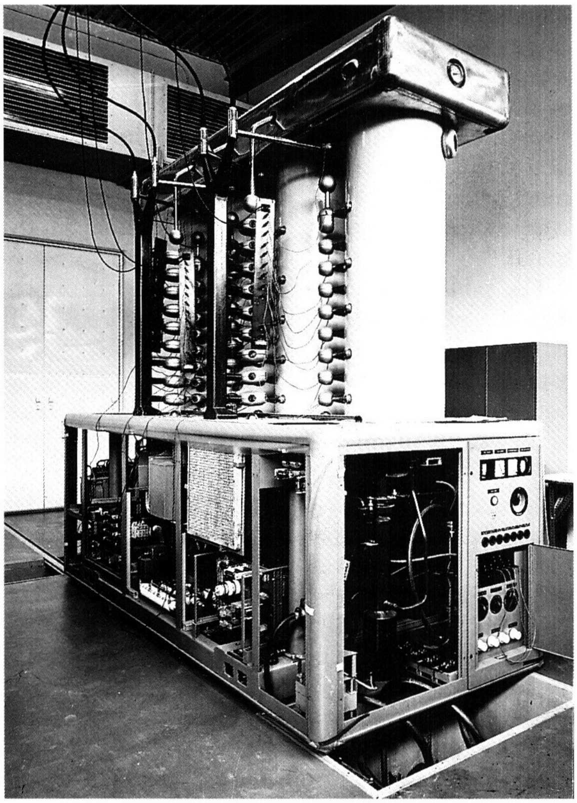
There were also 354 miles of high-voltage DC transmission line and 1,623 steel towers to erect, mostly in the South Island at heights of up to 4,200 feet and traversing much difficult country

This view into one of the *Photinia*'s holds shows the 25½ miles of coiled cable, which is fed out via the large sheave or wheel above the hold.



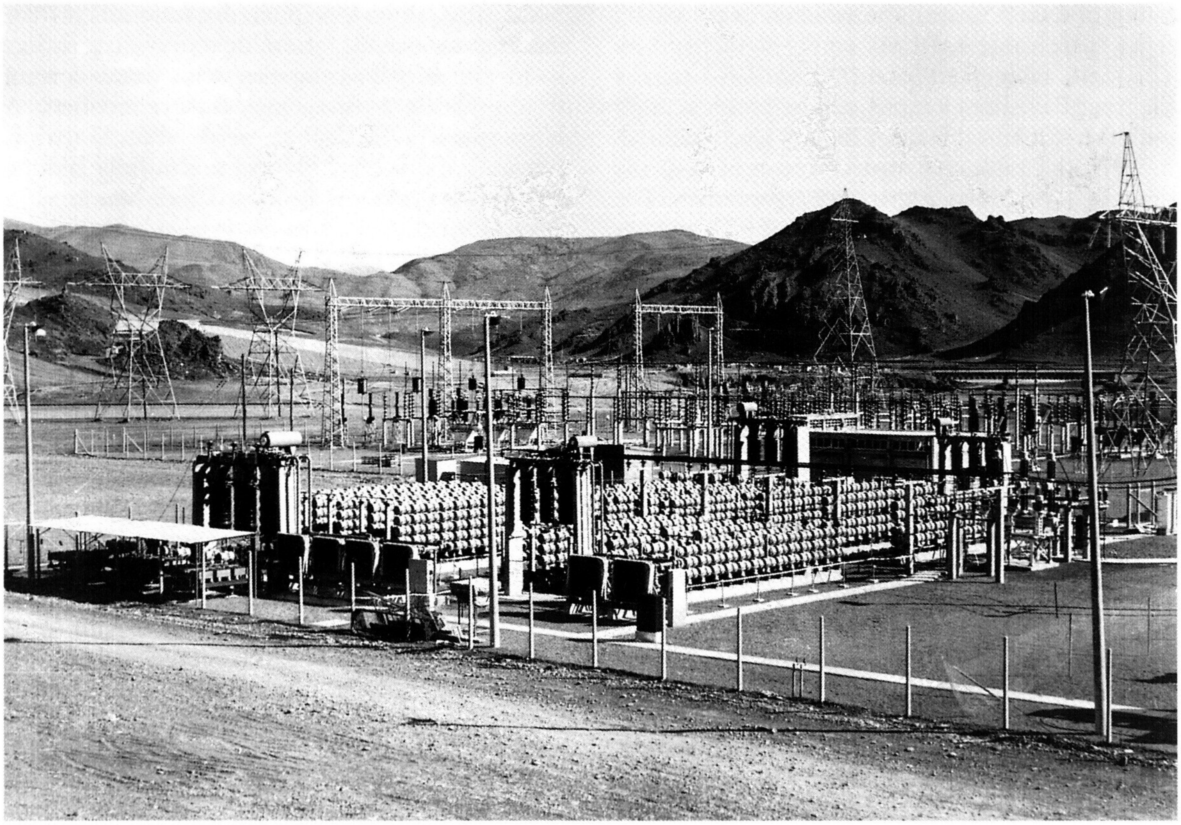
in North Canterbury and Marlborough. This aspect of the project employed more than 350 men. The specially designed aluminium and steel transmission line conductors were made in a factory in Auckland. By early 1963 more than half the towers were up and a start had been made on the lines. The line was completed in January 1965, an astonishing achievement.

The project was commissioned on schedule on 1 April 1965. The Prime Minister, Keith Holyoake, officially opened the cable and Benmore at the same time on 15 May when he pushed a switch at Benmore station. For the year ending



Right: Much of the justification for the huge Benmore project was its association with the high-voltage DC link to the North Island. These Swedish ASEA mercury-arc valves, here being assembled, were a feature of the DC link. They transform AC current into high-voltage DC current.

Below: The process of converting AC current to DC produced a large range of harmonic frequencies, which interfered with telephone lines and electrical control systems over a considerable distance. This harmonic-filtering equipment was installed at the Benmore station as a result.



March 1966, 13.3 per cent of the North Island's energy was transmitted via Cook Strait. The link was working well, albeit at half capacity because of a need for harmonic-filtering equipment at Benmore. The harmonics generated by conversion into DC interfered with telephone toll circuits, street lighting and hot-water control systems, particularly in the north of the South Island.

The cables have now been in service for more than the twenty years that initially was regarded as their life, and they form a vital part of the national power system. The value of the link is not in dispute, with between 20 and 30 per cent of the North Island's energy needs being supplied via the cable. After an exceptionally dry winter in the North Island the cable supplied 38 per cent of the island's needs between September 1969 and March 1970, with the proportion at times reaching half the total. For the year ending March 1973, 32 per cent of the North Island's energy consumption was supplied via the cable, again because of drought.

In 1976 the system was modified so that up to 400 MW could be sent from north to south, and this was immediately taken advantage of in the dry seasons of 1976 and 1977, and to help with the filling of Lake Pukaki. The wisdom of providing for a spare cable has been amply demonstrated. The first cable fault occurred in 1973 at the Fighting Bay shore joint. A similar problem arose with the second cable in 1976, and again in 1980. In 1976 the cable that had to be repaired at the time of laying first experienced problems. The *Photinia* was recalled and in June 1977 another complex splice, similar to the original one, was made to replace the repair joint. The lengths of the cables suspended over rocks near Oteranga Bay are subject to tidal action, but only recently has this become troublesome. The first problems came in 1981 when gas leaked from the jointed cable. This was repaired over the summer of 1982–83. When a further leak was detected subsequently it was decided not to undertake a much more difficult repair, but rather to use the cable only in emergencies and at half capacity. In May 1988 the sealing joint at the Oteranga Bay end of one of the good cables exploded. This was repaired with much urgency within a few months.

In order to cope with the new hydro-electric power being developed in the South Island, extra transmission capacity will be needed from the early 1990s. The possibility of increasing the capacity of the link was investigated from 1987, and it was decided to expand and upgrade the link to operate as a hybrid system, with a new link at −350 kV and the existing one changed to +270 kV instead of ±250 kV. The capacity will be increased to 1,240 MW as a result. In February 1989 a contract was let to Norwegian and Swedish firms to design, manufacture and install three 350 kV undersea cables, and in March another contract was let to a Swedish firm for two 'solid state' thyristor convertor terminals — the modern equivalents of the mercury-arc rectifiers — for the new link, together with a new control system for the existing mercury-arc rectifiers. A Norwegian cable-laying ship, the *Skagerrak*, arrived in February 1991 and successfully laid the three new cables in February and March. The interconnection of the two islands has been strengthened, and Latta's vision is even more a reality.

CHAPTER NINE

Development of the Waitaki River

WHEN THE PRIME MINISTER, Keith Holyoake, opened the Benmore power station in May 1965 he marked the completion of the first stage in the harnessing of the upper Waitaki River and the establishment of a unified transmission system for the whole country., Benmore was needed because of the North Island's insatiable demand for power and lack of water-storage capacity.

In the late 1940s investigation of the Waitaki was concentrated on a site suitable for a concrete dam at Blackjacks Point. The surveys were carried out in primitive conditions.[1] At one camp more than a dozen tents were shredded by extremely strong winds. Meals were cooked in a camp oven on an open fire, showers were taken under a 7 lb treacle tin with a gravity feed from a nearby stream, and the weekend bath was enjoyed in a galvanised-iron over-sized baby's bath.

Benmore

Great advances in large earth-dam techniques allowed consideration of a new site for a huge dam three miles downstream at Benmore, where there were good foundations under 60 feet of river gravel.[2] This structure would be far larger than any earth dam built previously by the Ministry of Works. From 1955 a small survey team was based at the site. The proposal for a station at Benmore was announced in 1956 at the same time as the Cook Strait cable. The Ministry of Works' investigations formed the basis of a submission to Cabinet in August 1957. The ministry's initial thinking on the development of the Waitaki basin as a whole, which would utilise a catchment area of nearly 5,000 square miles, involved a chain of some thirteen stations with a combined capacity of 1,570 MW, including another dam below Benmore and development above it in the Mackenzie Country. The mean river flow at Benmore was 12,000 cusecs.

A shift from Blackjacks Point would have significant advantages. The storage lake would be larger, the Ahuriri River could be taken in, and the increased head raised the potential capacity from 336 MW to 480 MW. (Following further hydrological analysis upstream, Benmore's planned capacity was increased to 540 MW in 1959.) The shift also eliminated one of two stations proposed earlier. Downstream, a single station below the Waitangi Bridge at Roseneath (later to be called Aviemore) at the head of Lake Waitaki could use all the head available between the Benmore and Waitaki power stations.

The Benmore dam site was a couple of miles downstream from the Ahuriri confluence, with its right abutment against a short spur running from the ridge separating the Ahuriri Valley from the Waitaki River. The original intention had been that water would be conveyed to a powerhouse further downstream via a tunnel from the Ahuriri branch of the lake. The design submitted to Cabinet, however, placed the powerhouse at the foot of the right abutment ridge, where there would be good foundations for the intake structure, penstocks and powerhouse. The spillway structure was to be at the left abutment. This design was accepted.

The Ministry of Works envisaged using its own work-force as well as contractors, with the contracts to be let in sections to control the outflow of capital. With Roxburgh nearing completion, there would be a gradual release of workers and accommodation to the proposed village of Otematata, three miles downstream from the dam site and not too far from the proposed Aviemore project.

The Ministry of Works recommended an immediate start, since the additional power would be needed by 1965. The justification for building Benmore was the power that would be made available for the integration of the two islands' systems. The South Island was expected to need only 180 MW from Benmore by 1970, whereas the combined increase in demand from both islands was likely to exceed the station's capacity. Hence the Combined Committee recommended that further stations be built on the Waitaki after Benmore. The government approved Benmore in October 1957, but with only two of the six machines, to serve the South Island rather than send power north. (In March 1961, at the same time as it approved the inter-island link, the government authorised four additional machines to bring the station up to its full capacity.)

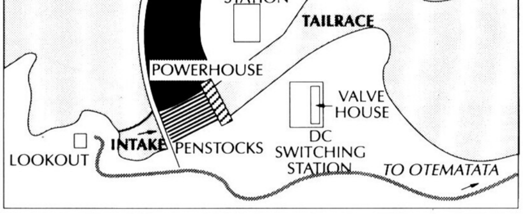
By 1958 design work was under way and the excavation of the massive diversion culverts had begun. These comprised two arched barrels, 41 feet high, 25 feet wide and 1,440 feet long. A model had been carefully tested; the barrels were to be largely unreinforced and would have to support both the earth-fill dam and 300 feet of water.

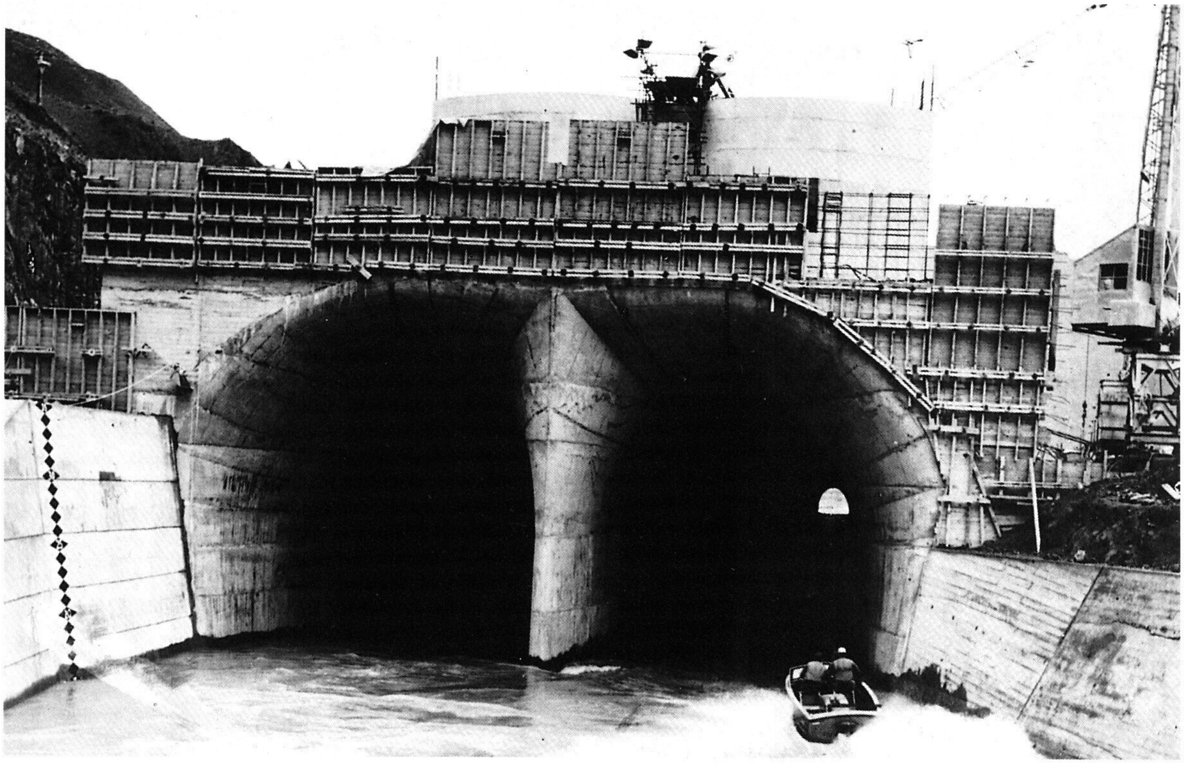
The transfer of some 850 buildings from Roxburgh was a big undertaking in itself, entailing driving by day and night through the Cromwell Gorge and over the Lindis Pass. At that time three-quarters of the 130-mile route was unsealed and not yet widened to modern highway standards, a daunting challenge for articulated trucks carrying two-thirds of a house or three huts.

Otematata, though temporary, was a carefully planned town of 'all electric' houses, with a block of thirteen shops, a police station, dental clinic, small maternity hospital, post office, doctor's surgery, social hall, churches, a cinema, library, sports facilities and a gymnasium. Many of these facilities were transported from Roxburgh. Some 650 houses were provided for families, while single men were accommodated in two camps with a total of 550 huts. At its peak in the mid-1960s Otematata's population was about 4,000, with a large proportion of school-age children. The Otematata District High School's roll reached some 540, and the Benmore Primary School's about 430.

As a result of its prior experience of running hydro villages at Mangakino and Roxburgh, the Ministry of Works at an early date set up a Welfare Association representative of the whole com-

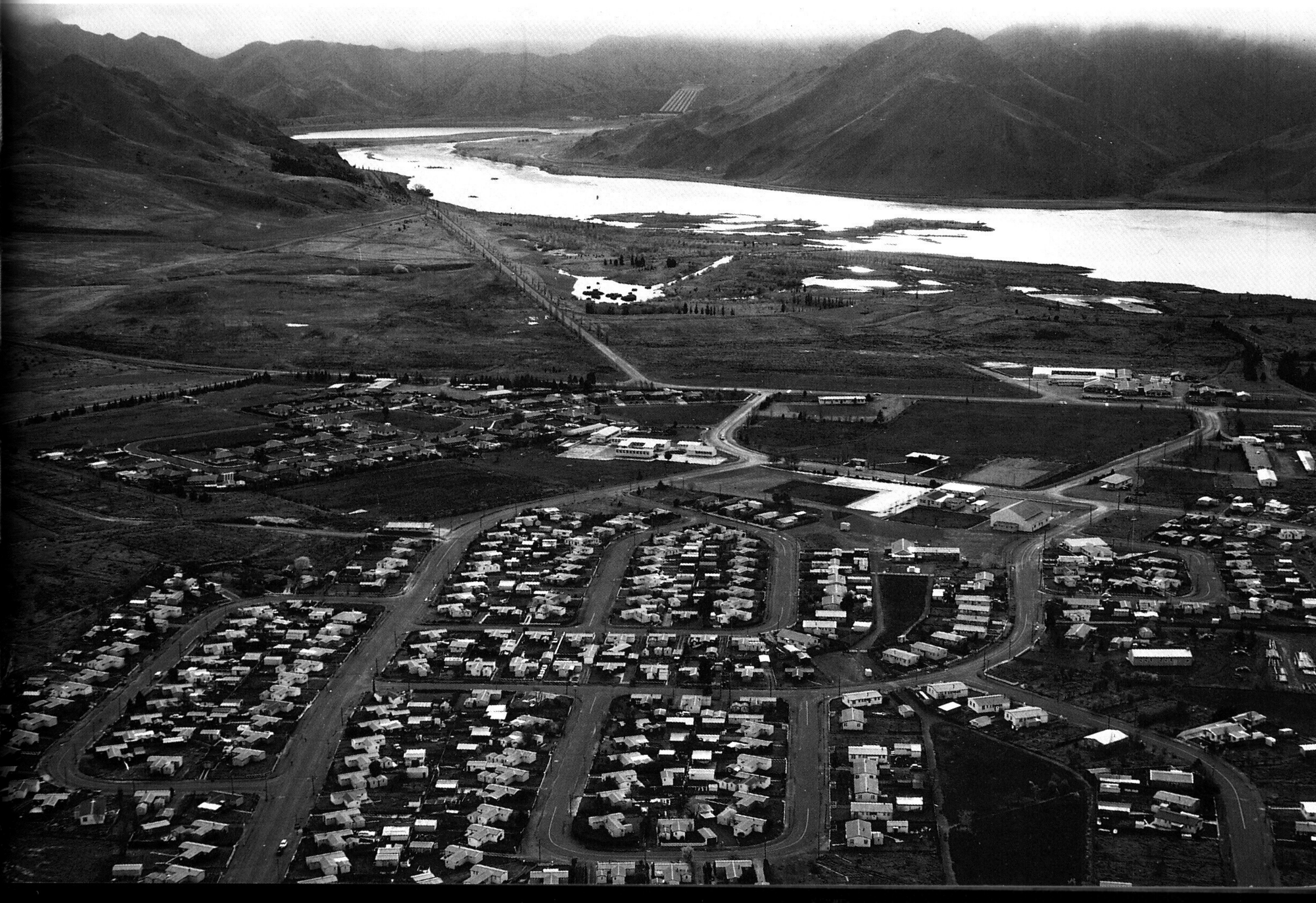
Benmore: Constructed 1958–65. Head 302 feet. A massive earth dam, 3,140 feet long and 387 feet high, with a width of 1,600 feet at the base and 35 feet at the crest. The volume of 16 million cubic yards of material for the earth dam and 500,000 cubic yards of concrete for various structures make this the largest construction project ever undertaken in New Zealand. The intake structure and the penstocks are at the right abutment. Six penstocks 650 feet long with an internal diameter of 17 feet 6 inches, were built in 318 8-foot-long pre-stressed concrete sections, each weighing 58 tons, a considerable technical achievement. Six turbines drive generators, which at 90 MW were more than twice the capacity of the then largest in the country at Roxburgh. The rotating parts of each turbine and generator combined weigh 300 tons, and the diameter of each rotor is 25 feet 6 inches. The 124-foot-high spillway structure at the left bank has four radial steel gates at the water level and two sluice gates in its base. The spillway channel is nearly 1,500 feet long and has deflector blocks at the bottom. At 30 square miles, Lake Benmore is the largest artificial lake in New Zealand. The combination of provision of high-voltage DC for the North Island link and AC for the South Island network was unique. The generators are connected in parallel by heavy-current busbars, a departure from usual practice. There are six transformer banks, four for the DC converter station, with mercury-arc valves changing 110 kV AC to 500 kV DC, and two for the South Island AC system. The total capacity of 540 MW made the station the largest in the country until Manapouri was built.

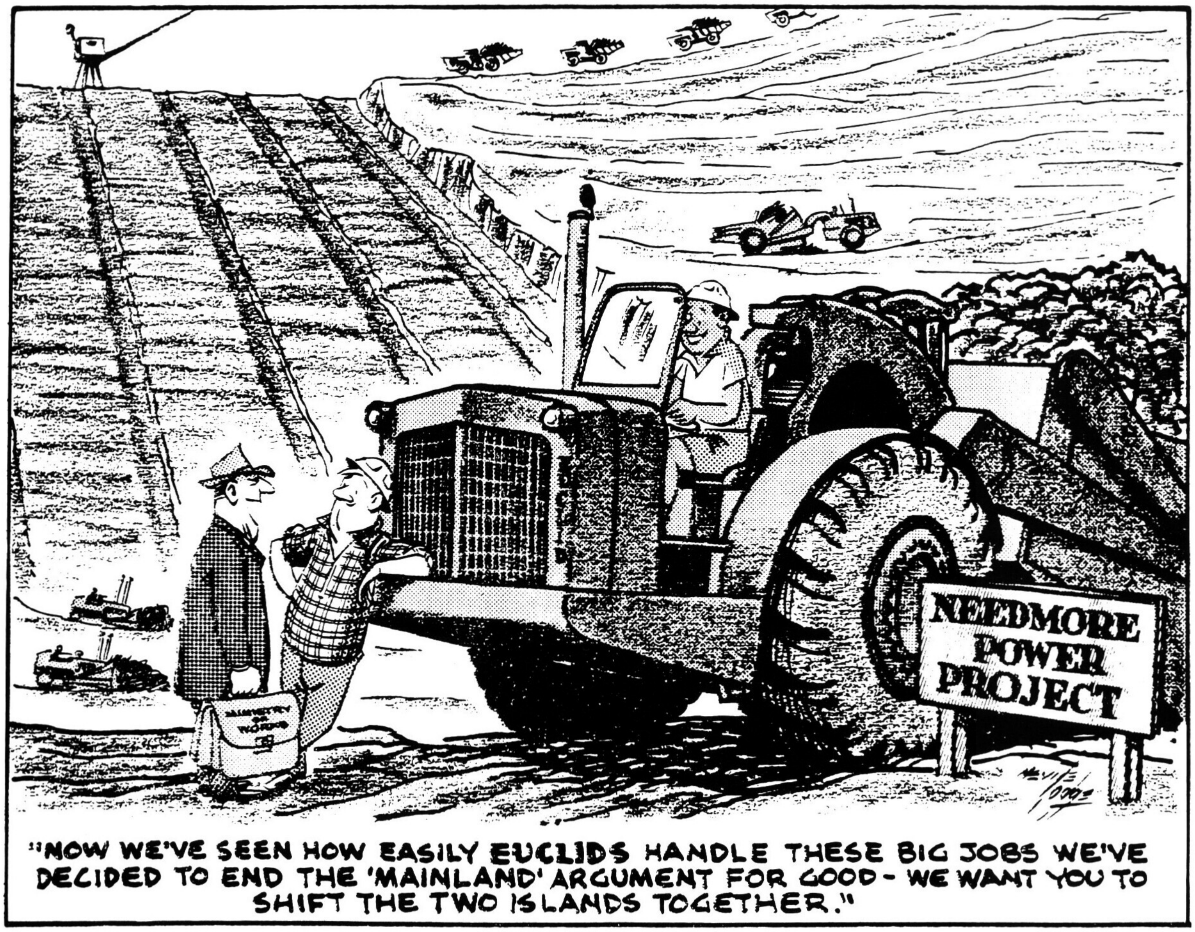




Above: Benmore's diversion culvert comprised two arched barrels, as shown here. These had to support the enormous weight of the earth dam that was to be built on top of them. This photograph shows an inspection of the culvert by jet boat just after the diversion of the Waitaki River in August 1960.

Below: The Ministry of Works town of Otematata in the Mackenzie Country, although a temporary construction town, was well provided with facilities and reached a population of about 4,000. The partially completed Benmore scheme is at the top middle.




NEEDMORE
POWER
PROJECT
"NOW WE'VE SEEN HOW EASILY EUCLIDS HANDLE THESE BIG JOBS WE'VE DECIDED TO END THE 'MAINLAND' ARGUMENT FOR GOOD - WE WANT YOU TO SHIFT THE TWO ISLANDS TOGETHER."

A feature of the Benmore project was the spectacular scale of the earthmoving required. Here the cartoonist Lodge uses the image to suggest a novel solution to South Island grievances about power going north.
Nevile Lodge, *Lodge Returns*, 1964

munity as the co-ordinating body for establishing clubs (of which there were eventually more than 60) and social amenities. The Project Engineer was the de facto mayor, and the Welfare Association was in effect a town council. It published a weekly newspaper, the *Otematata Chronicle*.

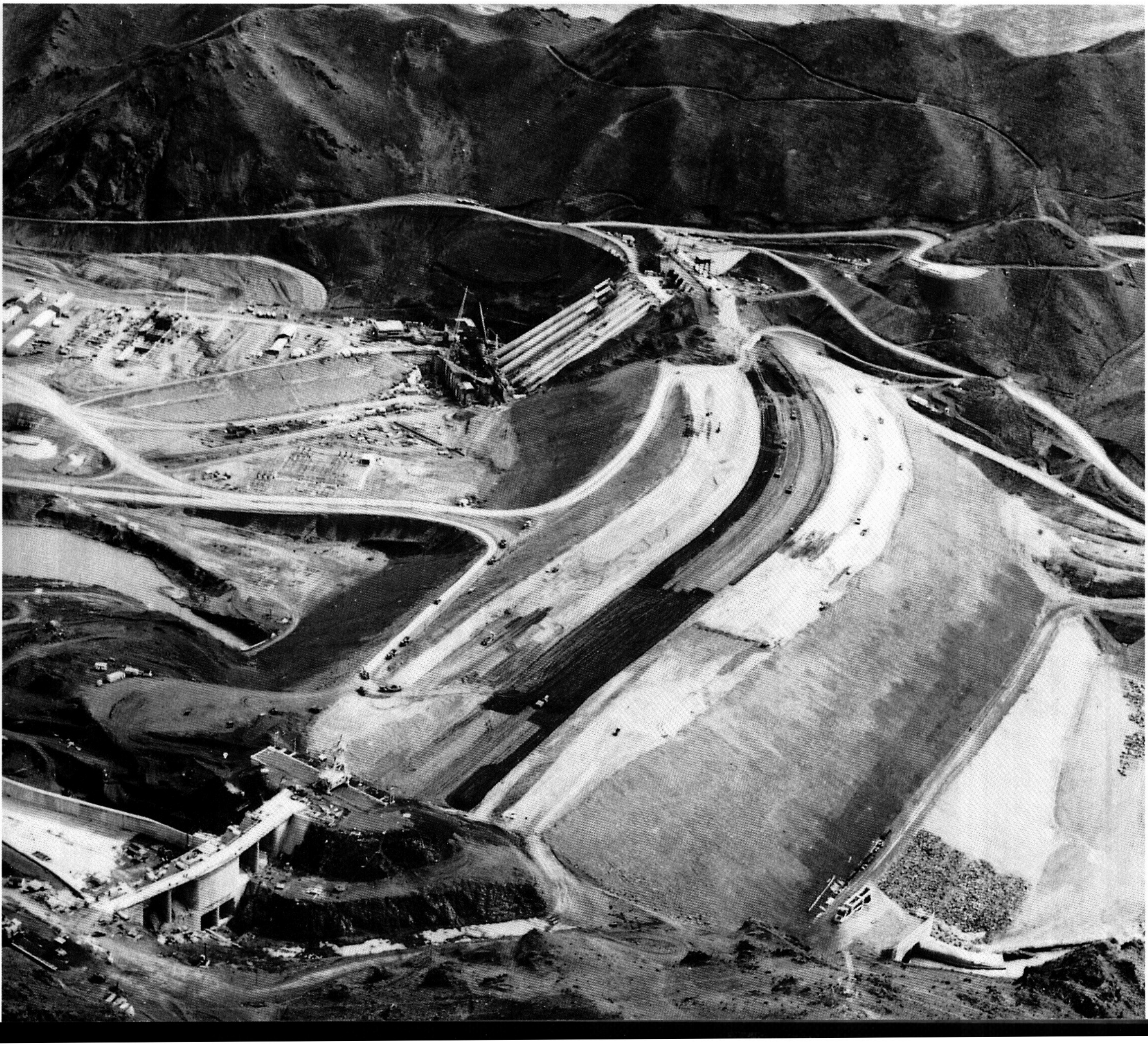
On-site work proceeded steadily, with 1.5 million cubic yards of material being shifted in the year to March 1960. Some 450,000 cubic yards had been removed from the diversion culverts alone by the time they were excavated fully in July 1959. The rock obtained from these excavations was stockpiled for use in the downstream face of the dam. At the same time the upstream coffer dam was being prepared for diversion, and at the dam site itself the core trench was being excavated and grouted, and more than 300,000 cubic yards were put in place for the dam's shoulders. Diversion had been scheduled for 1961 but was accomplished on 5 August 1960 during the preceding winter, when river flow was low. Once this was achieved the earth dam grew rapidly, with some 2.5 million cubic yards of material being placed within a year. The Electricity Department now called tenders for the six turbines and generators.

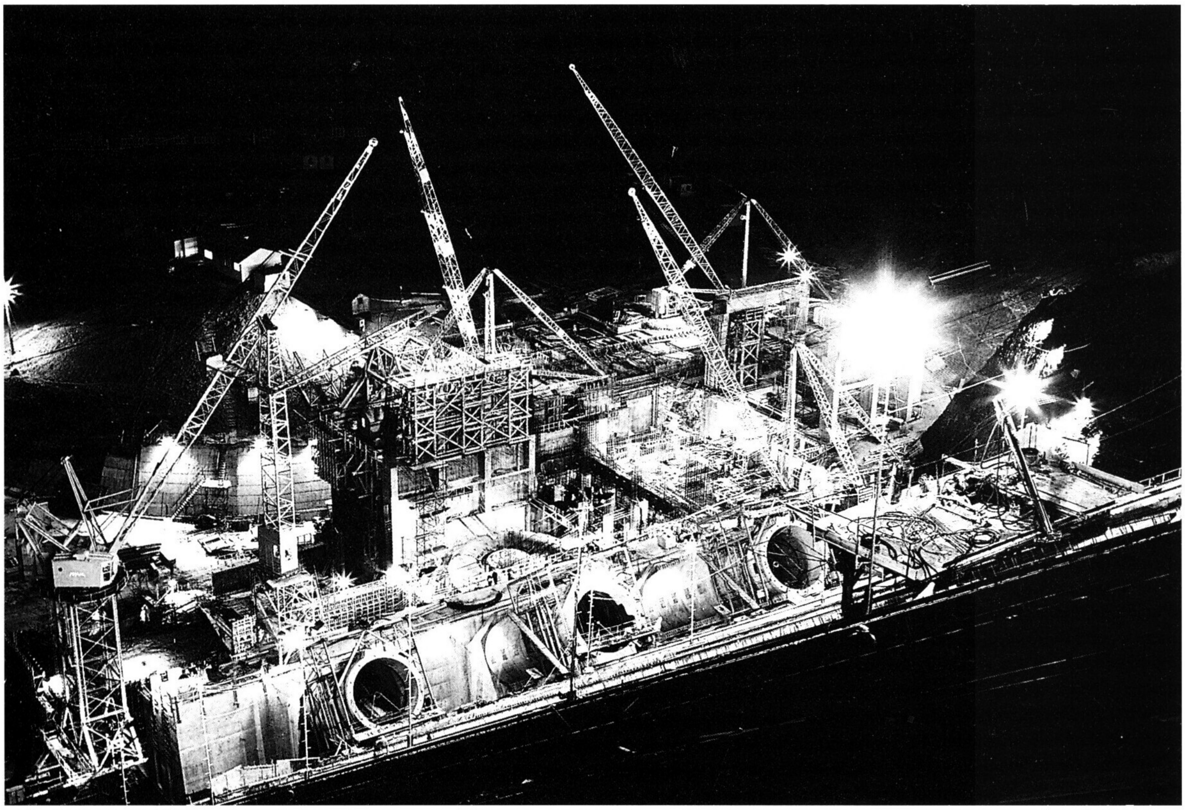
The Roxburgh project had generated a substantial amount of employment and expenditure in Central Otago, and Oamaru and North Otago now looked forward to similar benefits. Local interest remained high throughout the construction period, with newspapers reporting progress. The spectacular construction of the great dam and the sight of huge earthmoving machines attracted hosts of visitors, as many as 6,000 a day and 200,000 in a year being recorded at the observation point above the dam site. There was also widespread awareness that the electricity generated would be sent north rather than encouraging new industry in the south. The boom thus offered only temporary benefits. Among the scheme's disadvantages was the fact that Lake Benmore would inundate some of the prime flat grazing land of several high-country stations. Agreements on compensation for these losses were reached.

By 1962 the dam was half complete. Civil-engineering work was at a peak, with a workforce of 1,240, and 160 heavy earthmoving and compacting machines dealing with 16,000 cubic yards of material each day. More than four million cubic yards were placed that year. Work had begun on the spillway, 100,000 cubic yards of concrete having been poured there by March 1962. There had also been some concreting of the intake structure on the right of the dam. More than 600,000 cubic yards of gravel and rock had been excavated from the powerhouse and tailrace areas by this time. Contracts for turbines and generators had been let, which allowed the design of the powerhouse to proceed while its site was excavated. Benmore's first three machines were due to be commissioned in April 1965, and the other three a year later.

By 1963 the dam was three-quarters complete and the concrete substructure for the powerhouse was half finished. Separate contracts had been let for the control and office blocks, and the mercury-arc-converter valve house. The spillway outfall channel had to be extended by 500 feet when unsuitable rock was found during excavation for the deflectors. The loss by fire of the plant-repair shop and tools was rapidly made

This aerial view shows Benmore's massive earth dam with its core (the darker material in the middle of the dam) clearly visible. In the foreground is the long concrete spillway, and at the other end of the dam lie the intakes and six concrete penstocks, which are under construction. The diversion culvert can be seen at the base of the upstream side of the dam.





Construction of Benmore's penstocks and powerhouse continued at night. The penstocks were made in large prestressed-concrete sections, which are here shown being installed.

good by replacement of the building and equipment. The first turbine was now hydraulically tested and the penstocks were installed.

The final year of construction in 1964 saw a work-force of 1,550 engaged, largely at Benmore but also on the beginning of construction work at Aviemore. By May the Benmore dam had reached crest height, more than four and a half million cubic yards of material having been placed in it during the previous year. The powerhouse was almost finished and ready for the installation of generators. Much of the intake and spillway structures had been completed, and all the penstock sections were installed by September 1964. Two units had been installed in the powerhouse.

The Ministry of Works had a considerable commitment to the restoration of the landscape. Before the lake was filled, the ground was cleared of trees and scrub, and some 50,000 trees were planted near the dam and at points along the shoreline. Picnic spots were created for boat users.

On 30 November 1964 the two 153-ton steel diversion gates were lowered and the culverts were plugged with concrete and rock fill. The filling of the lake affected generation at the Waitaki power station downriver until water reached the dewatering sluices, some 220 feet above the riverbed. Within a week of the gates being closed, delayed melting of snow brought down extra water in the tributaries, which helped considerably. Downstream, a great rescue operation was in progress, with volunteers and government officers removing more than 50,000 fish from pools in the nearly dry riverbed. By mid-December the lake was sufficiently full for water to be released through the spillway. The transmission lines and undersea cables from Benmore to Haywards were now almost ready to take the first power.

The turbines were tested early in January 1965, and Lake Benmore was full just before the target date of 18 January. The first generator was already producing power and two more were being tested; 60–100 foot high waves over the deflector blocks added to the spectacle. The first three units

Opposite: The completed Benmore dam, and the lake stretching back into the Mackenzie Country. Water races down the spillway.

were commissioned ahead of schedule in January and March, and a joint opening ceremony for Benmore and the Cook Strait cable took place on 15 May.

Fate had been kind to Benmore. The project had cost less than predicted, and was completed ahead of schedule. Even the snows of the previous winter had melted late, allowing the dam to be filled rapidly. The fourth unit was commissioned in October, the fifth in December and the last in May 1966.

Aviemore

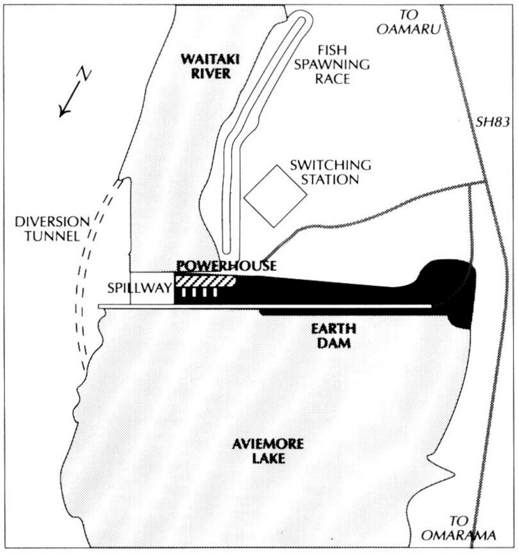
The Aviemore dam, which contains a massive amount of concrete and has huge penstock and spillway structures, was the largest concrete dam built in the country before the Clyde dam.[3]

There had been some work at the Aviemore site for a number of years before the project was begun in earnest. Indeed it had first been investigated in 1927 as a possible site for the Waitaki dam, which was eventually built downstream. By 1960 investigative drilling was under way. In 1961 the Power Planning Committee recommended that Aviemore go ahead, with commissioning in 1968.

The Cabinet Works Committee approved an immediate start in October 1962, but with a commissioning date of 1969–70. At this time the need for power was seen as less urgent because it was expected that Manapouri would be commissioned in 1968. However, delays to Manapouri meant that in 1964–65 work on Aviemore was accelerated and the commissioning date became 1968 once again.

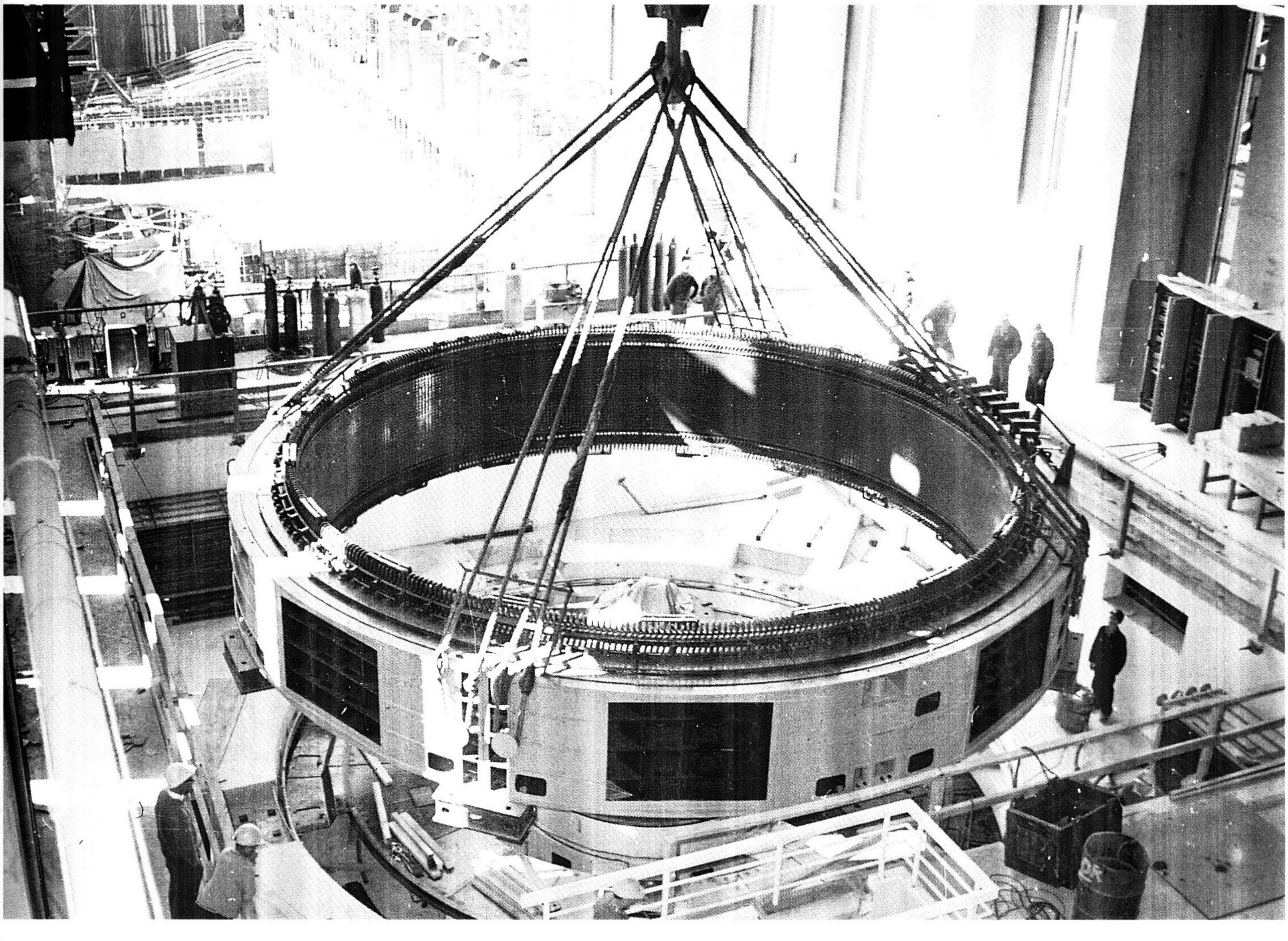
The dam site was just below the Waitangi Bridge, four miles upstream from the Waitaki power station and nine miles from Otematata. The geology of the area was complex because of the Waitangi fault underneath the riverbed. After investigations that were completed in 1962, the Ministry of Works proposed a concrete dam housing the intakes and spillways on the left (Canterbury) side, where there were good rock foundations, in combination with an earth dam on the right (Otago) side, where there was soft country, including coal measures, overlying the fault line. The penstocks leading to the powerhouse below would be formed within the concrete of the dam. Great care was taken with the design, both to house the large generators and to enhance the station's external appearance, since it would be visible to the considerable tourist traffic on the main highway. The proposed Lake Aviemore would affect four sheep runs along the river. One run would lose its homestead along with its flat land; another's irrigation system was on the land where the dam would be built. Two stations on the Canterbury side would require compensa-

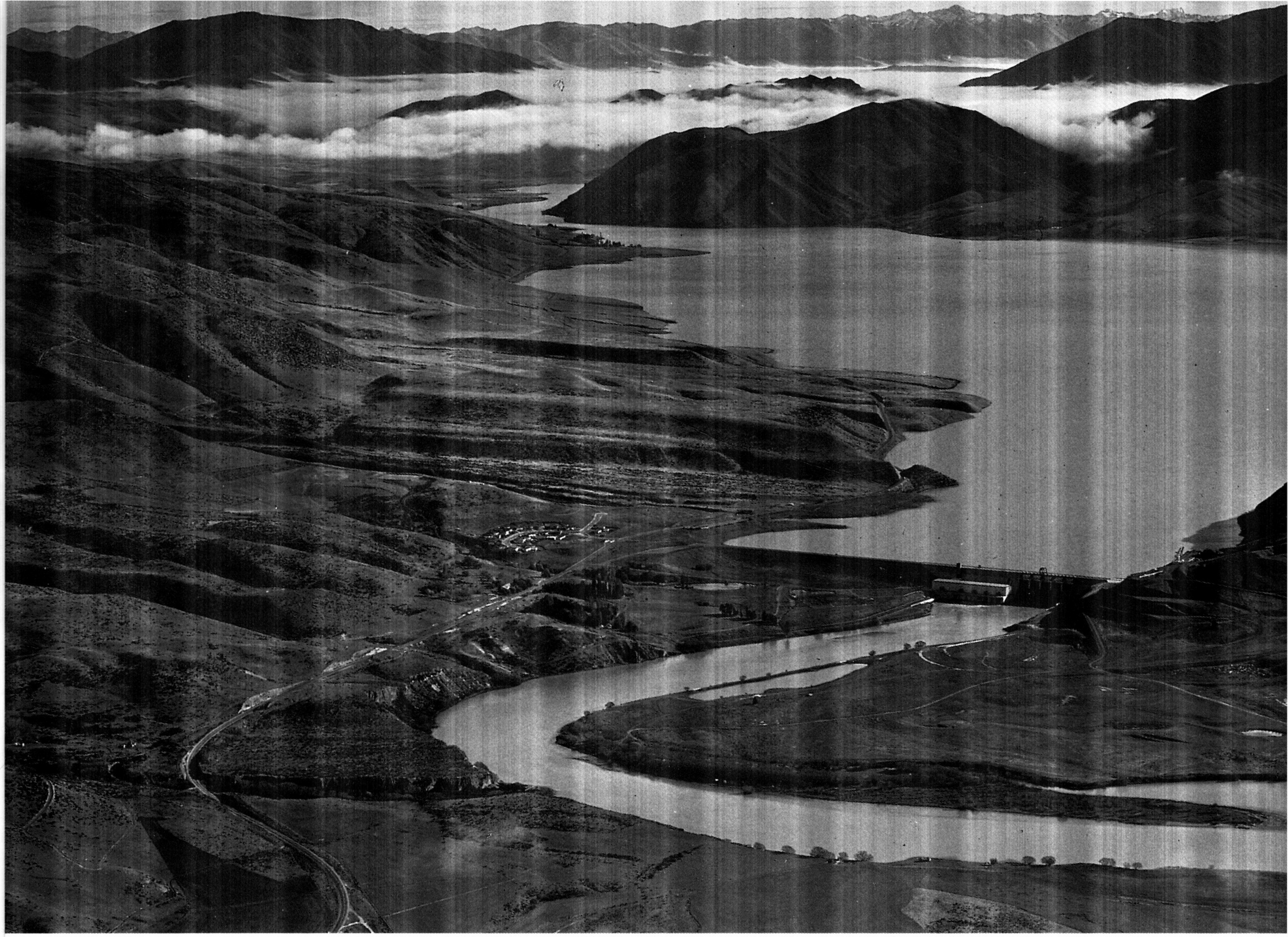
Aviemore: Constructed 1962–68. Head 122 feet. A combined concrete gravity and earth dam, 184 feet high and with a 984-foot-long concrete section and a 1,476-foot-long earth section, contains 600,000 cubic yards of concrete and 1.6 million cubic yards of other material. The intake structure has four intake gates and two sluice gates. Four steel penstocks, 23 feet in diameter, lead water to turbines that drive 55 MW units. The generators are the largest installed in New Zealand, the rotors being 26 feet in diameter and weighing 210 tons, but because of the lower head, they deliver less power than those of Benmore. The concrete dam contains five 84-ton spillway gates, 52 feet wide and 32 feet high. Total capacity is 220 MW.



Opposite above: Early days in the construction of the Aviemore station. The dam is beginning to rise at the right, and the base of the powerhouse, with the ends of the penstocks covered with tarpaulins, is at centre. The penstocks were formed within the concrete of the dam.

Opposite below: Installing one of the stators in Aviemore. The generators are extremely large — the rotors weigh 210 tons and are 26 feet in diameter.





The completed Aviemore scheme, showing the combined concrete and earth dam and the lake stretching back to the Benmore dam.
Whites Aviation

tion for temporary loss of access until the dam provided a new route, as well as for loss of land.

As with Benmore, both departmental and private contract workers were used. Site clearance began at once in November 1962, and access roads were built while alternative methods of river diversion were considered. It was decided to drive a tunnel through a rock bluff on the Canterbury side. This was 1,530 feet long and had the largest cross-section in New Zealand, being 29 feet wide and 40 feet high. The tunnel was begun in December 1963, and completed and lined with concrete by mid-1965. On 1 August the river was diverted and coffer dams were created so that work on the dam's foundations could begin. The New Year floods of 1966 tested the coffer dam and the diversion tunnel, but both held up.

Work had also proceeded on the powerhouse and dam foundations on the right bank, where over 300,000 cubic yards of material were excavated. In early 1966 construction of both the concrete and earth sections of the dam began in earnest. The concrete dam was made in eighteen continuous poured blocks. A record rate of pouring was achieved by using modified cement, without the need for cooling coils.

In June 1966 the first 160-foot-long penstock sections were ready for installation after a difficult journey from Christchurch, where they had been fabricated. By March 1967 the concrete dam was two-thirds complete and half of the penstock sections were in position. Some 300,000 cubic yards of concrete had been poured that year. The earth section of the dam, into which 1.1 million cubic yards of shoulder and core materials had been placed in a year, had nearly reached its crest level. Excavation of the powerhouse, dam foundations and tailrace channel had involved a further 410,000 cubic yards. Work on the powerhouse was well advanced and the first generating machinery was being installed.

In August 1968 the entrance to the diversion tunnel was closed by a steel bulkhead and plugged with concrete, and Lake Aviemore began to fill. The twelve-square-mile lake backed up to Benmore's tailrace, and was second only to Lake Benmore in size. The project was handed over to the Electricity Department for commissioning on time. The Power Division of the Ministry of Works congratulated itself by describing the project as 'notable for economy in design and construction . . . [and] completed at $3.5 million less than estimate'.[4] The first two machines were commissioned in August 1968, the third in February 1969 and the fourth in July.

For the first time an artificial spawning ground was created, just downstream of the dam which had blocked access to the previous upstream grounds in the tributary Deep Stream. A hairpin-shaped expanse of gravel bed and water was formed and fed by an auxiliary turbine in the station; trout gained access to it via two concrete fish ladders. In 1974 the combined Benmore and Aviemore projects received the New Zealand Institution of Engineers' Environmental Award for restoration work and environmental enhancement.

The Upper Waitaki development

Continuing the hydro-electric development of the upper Waitaki would involve taking advantage of the outflow from the three lakes — Ohau, Tekapo and Pukaki — at a higher altitude than Benmore, by their linking through nearly 40 miles of canals, and also making use of the considerable head between Lakes Tekapo and Pukaki.[5] The former, with a mean discharge of close to 3,000 cusecs, was nearly 700 feet above the latter, which discharged more than 5,000 cusecs and was about 450 feet above Lake Benmore at that time.

At first it was suggested that the Fork Stream could be diverted into Lake Tekapo to increase the water resource for a new power station near the lake's outlet, but this proposal was later dropped. Instead, water from the lake would be conveyed by a canal to Lake Pukaki, where the Tekapo B station would make use of the head between the two lakes. Lake Pukaki could be raised further by a new high dam that would double its storage capacity. Water from the lake would then travel along a canal to the Ohau A power station on the north bank of the Ohau River. Lake Ohau, which discharged 81 cumecs, could also be raised or at least controlled for storage purposes. Another canal would carry water from Lake Ohau into the Pukaki–Ohau canal to increase the flow available

The Upper Waitaki development

Tekapo B: Constructed 1970–77. Head 146 metres. The 27-kilometre Tekapo canal, with a capacity of 120 cumecs, carries water from the tailrace of Tekapo A station at the outlet of Lake Tekapo to the Tekapo B powerhouse. This was to be surrounded by water when Lake Pukaki was raised, and so the building's substructure housing the generators and control room is waterproofed. There are two 1,275-metre-long steel penstocks, 4.2 metres in diameter, built in 49 sections with couplings. The penstocks are cased in concrete below lake level. Flexible joints connect the penstocks to the powerhouse in a 'dry well'. A special feature is the elimination of a surge tank by the use of a vernier relief valve. The penstocks take water to two turbines that operate over a varying range, depending upon the level of Lake Pukaki. The output of the generators varies between 76 and 90 MW but is usually stated as 80 MW, giving a total capacity of 160 MW. This station, like the three Ohau stations, is remote-controlled by radio from Twizel.

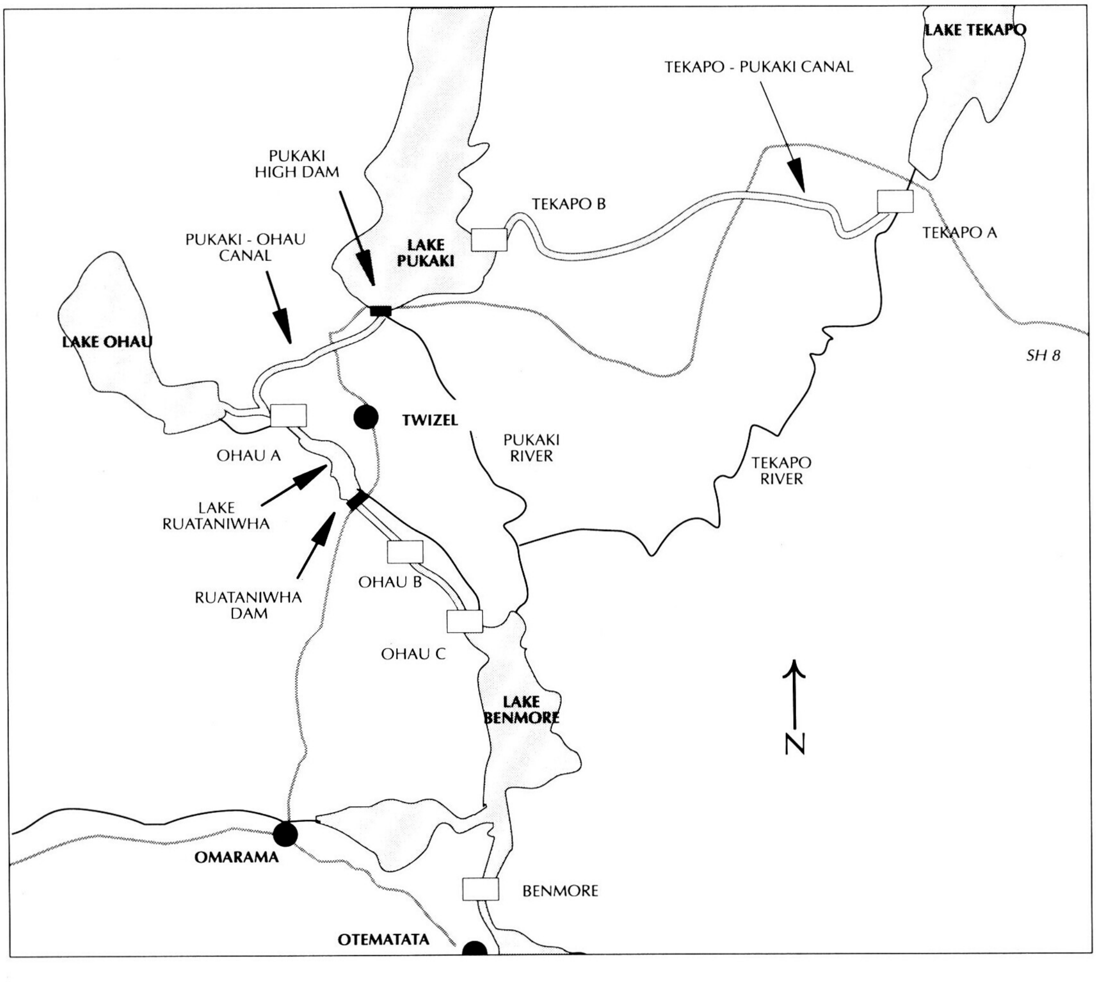
Pukaki high dam: Constructed in 1971–77 at the outlet to Lake Pukaki. It is an earth dam, 61 metres high and 823 metres long, made of an impervious silty gravel core supported by gravel shoulders. The dam, containing 4 million cubic metres of material, raised the lake by a further 37 metres to close to the level of Lake Ohau, allowing water to flow along the Pukaki–Ohau canal. The old low dam was submerged in the process. A 670-metre-long and 61-metre-wide concrete spillway with five steel gates lies on the eastern side, and a 188-metre-long and 46-metre-wide lake outlet structure with four steel gates on the western side. The lake is controlled over a range of 14 metres. Water is fed into the 12-kilometre Pukaki canal, with a capacity of 560 cumecs, which leads to the Ohau A power station. An 8.4-kilometre canal with a capacity of 200 cumecs from the Lake Ohau control structure joins the Pukaki canal, and a 1-kilometre canal, with a capacity of 560 cumecs, takes the water from both lakes to the power station.

Ohau A: Constructed 1973–79. Head 58 metres. Four 5.8-metre penstocks, 230 metres long, deliver water to four 66 MW units, giving a total installed capacity of 264 MW. Because of technical problems the units have been de-rated and the effective total capacity is 248 MW. From the tailrace of Ohau A water travels along the river course and is dammed to form Lake Ruataniwha, a surge reservoir. The main Ruataniwha dam is 240 metres long and 43 metres high and there is a low wing dam 480 metres long. Water from Lake Ruataniwha is carried 2.5 kilometres downstream to the Ohau B station by a 10.1-kilometre canal with a capacity of 560 cumecs.

Ohau B: Constructed 1977–83. Head 48 metres. The four 53 MW units give a total capacity of 212 MW. Its penstocks are 5.8 metres in diameter and 200 metres long. Water is carried by the same canal to the Ohau C station.

Ohau C: Constructed 1979–85. Head 48 metres. This is on the shores of Lake Benmore, and a twin of Ohau B, with a total capacity of 212 MW.

The entire project involved shifting about 50 million cubic metres of material for canals and other earthworks.


LAKE TEKAPO
TEKAPO - PUKAKI CANAL
PUKAKI HIGH DAM
TEKAPO B
TEKAPO A
PUKAKI - OHAU CANAL
LAKE PUKAKI
LAKE OHAU
SH 8
TWIZEL
PUKAKI RIVER
OHAU A
TEKAPO RIVER
LAKE RUATANIWHA
OHAU B
RUATANIWHA DAM
OHAU C
LAKE BENMORE
N
OMARAMA
BENMORE
OTEMATATA

at Ohau A. Downstream from Ohau A on the Ohau River there would be a dam to form a small lake (Ruataniwha) that would discharge into another canal, parallel to the river, to supply two further power stations (Ohau B and C) before the water entered Lake Benmore. The four new stations would have a combined capacity of 848 MW, and the increased storage would allow a million or more additional units to be generated each year by existing stations. This project would also have the indirect benefit of enabling a substantially more efficient use of other catchments in both islands.

There was clear justification for the control of all three lakes. The snow-melt flood period came when electricity demand was at its lowest, and the freeze when power was most needed. Without control, summer water went to waste. Planning for the use of the three lakes had been under way for more than a decade. A survey party based at Pukaki had from 1958 investigated possible canal and tunnel routes. Tekapo A power station already existed, and control structures on both Lakes Tekapo and Pukaki retained water for discharge downriver at times of low flow.

A report on the entire development released in November 1963 suggested that it would be uneconomic to raise Lake Tekapo further. This report advocated five stations, fewer than earlier proposals but one more than was eventually constructed; two stations rather than one were allowed for between Lakes Tekapo and Pukaki. In 1963 the Power Planning Committee recommended the approval in principle of the entire development and suggested a commissioning date of late 1972 for the first stage, the Tekapo–Pukaki section. The substantial fall from Lake Tekapo to Pukaki was across gravel flats and old moraines, and interrupted by the Mary Range some three miles from Lake Pukaki. At issue was whether the Mary Range could be bypassed without a special station, and where on the shores of Lake Pukaki the best site for a powerhouse might be. The latter question was a considerable problem, as preliminary drilling had not found suitable foundations anywhere.

The options were to raise Lake Ohau by 50 feet or Lake Pukaki by 100 feet or more. Both would have considerable consequences for landholders. Raising Lake Ohau would flood 6,000 acres of grazing land and affect a number of runs, several seriously. It would also submerge eighteen miles of roads, change the scenic character of the lake and interfere with fishing. Control of Ohau would cost less than a new high dam at Pukaki but would face much more opposition, including strong fishing interests and the Nature Conservation Council, an advisory body set up in 1963.

Pukaki had already been raised and its natural range changed. The advantages of raising Lake Pukaki by at least 100 feet were several: an extra 200 GWh of energy per year; possible elimination of a power station; reduced canal earthworks; simpler construction of Tekapo B power station; and increased total water storage capacity, which would add a potential of 600 GWh down to the Waitaki station, and up to 1,000 GWh if the lower Waitaki were to be developed.

Set against the gains would be the loss of the existing Pukaki low dam. Furthermore, less power would be available between Tekapo and Pukaki with the loss of a substantial proportion of the head, and the filling of Lake Pukaki would deprive the hydro-electric stations downriver of their water for a year. The main highway to Mount Cook would need to be relocated, and up to 7,000 acres would be under water at the design flood level. A substantial number of runs would be affected, five homesteads submerged, and the village of Pukaki and its hotel would also be inundated. All this would cost much in compensation payments, but in the end it was decided to raise Lake Pukaki. When this was done, the lake would provide about 45 per cent of the country's total hydro-electric storage capacity.

The site on Ruataniwha station for the new construction town of Twizel was purchased in August 1965. The Mackenzie County Council preferred Pukaki as a site, but the Ministry of Works argued that Twizel had good soil, was flat and had plenty of space for both housing and works complexes. There was a good water supply, and trees along the Twizel and Fraser Rivers added to its attractiveness. The main highway and an airstrip were both close at hand.

It was clear that whatever development was undertaken would have a much greater impact in the Mackenzie Country than any previous electric power project had had on its local area. An interdepartmental committee drawn from Lands and Survey, the Department of Agriculture and the Power Division, Ministry of Works, was set up to examine these issues. The most important questions were the effect of the project on the working and economics of the pastoral runs, and the provision of water supply and irrigation. The existing major rivers, which provided both stock boundaries and water, would largely disappear as a result of the development. It was argued that it would cost too much in lost water to maintain the Tekapo and Pukaki Rivers, and fencing and the supply of water to stock were proposed.

As the peak of construction at Aviemore passed, the Ministry of Works, seeking to retain its experienced work-force for the next project, pressed for a decision on the Upper Waitaki development and the deployment of men to build the construction town at Twizel. But in 1966 the Power Planning Committee recommended the deferral of the Upper Waitaki on the grounds that the renegotiation of the Manapouri agreement had given the government considerably more power until the early 1970s. This compounded the anxiety about the future of the Aviemore work-force.

Early in 1967 approval was sought again without success. In June 1967 Tom Shand, the Minister of Electricity, visited the area and revealed that work would probably start the following year. He confirmed that Lake Pukaki would be raised and Lake Ohau controlled within its natural levels. This would make possible a shorter, high-level canal from Pukaki to the Ohau River, which would link with a canal from Lake Ohau to feed one power station (Ohau A) rather than two smaller ones. It was also decided that there should be three stations in the final stage below the lake (Ohau A, B and C).

In February 1968 the Ministry of Works again went to Cabinet seeking approval for the project. Shand was anxious for a solution both as Minister of Electricity and as Minister of Labour, but Treasury wanted to base the decision on the future demand for electricity. Demand was not nearly as high as had been expected, and there was no justification for retaining the work-force unless projects were already in the pipeline. Cabinet accepted this argument, drawing attention to Manapouri.

It was not until July 1968 that the Electricity Department sought approval in principle for the entire project. In the previous months Comalco and its Japanese partners had defined their power requirements for the Tiwai Point aluminium smelter, without making any final commitments. Treasury was now prepared to recommend a start on the first year's programme for Twizel and approval in principle for the whole scheme. This approval was finally given in August 1968.

In the course of investigation and design work in 1969 a major change was made in the Tekapo–Pukaki system. The higher level of Lake Pukaki and the rerouting of the canal around the head of the Mary Range enabled the omission of the tunnel through the range and an associated powerhouse. The head from the tailrace of Tekapo A to Lake Pukaki could now be developed through a single Tekapo B power station.

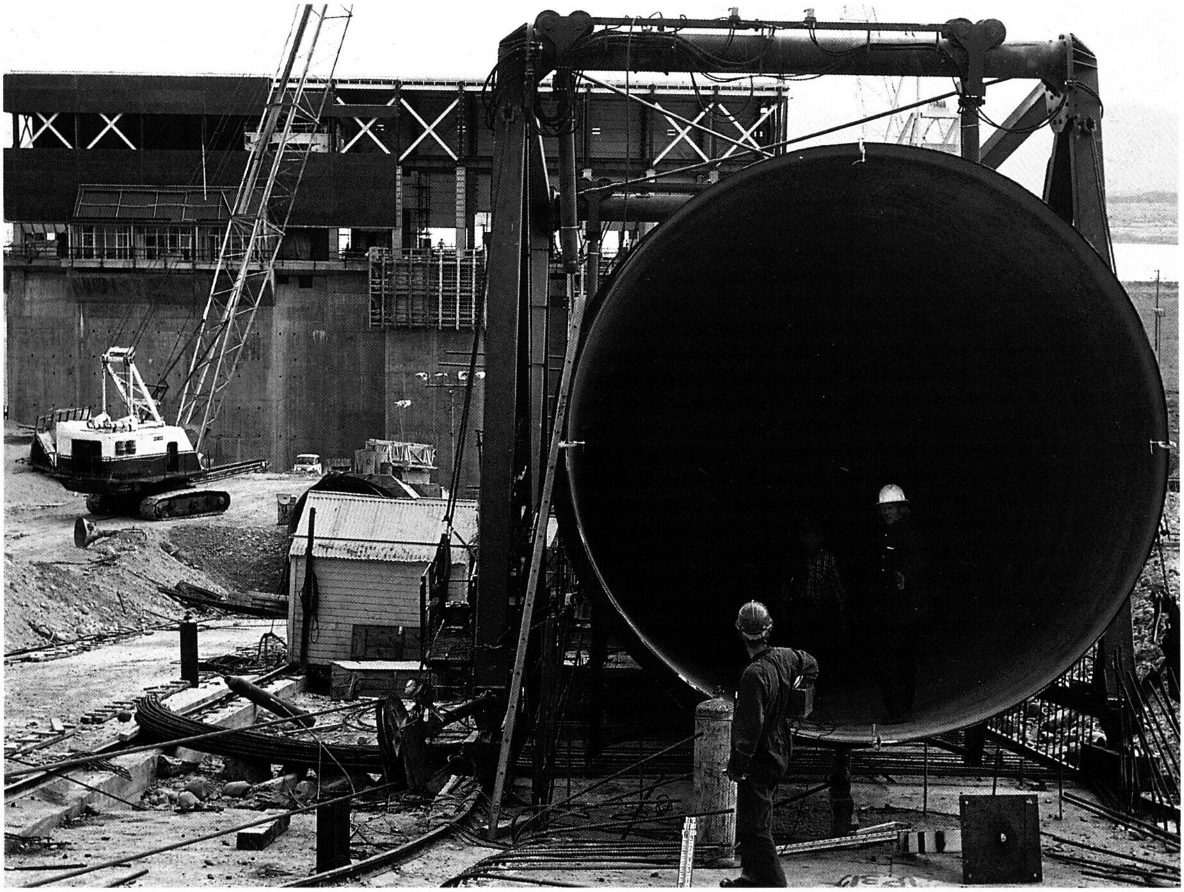
When negotiations on authorisation of the next stage of Twizel's construction and a start on the scheme itself opened in 1969, Treasury wanted to postpone the Pukaki dam works for four years, thereby reducing considerably the time available for lake filling. Both the Ministry of Works and the Electricity Department considered this timetable too tight. In the event, Twizel went ahead, but the dam was postponed for one year. The Tekapo–Pukaki stage of the development was now scheduled to be built between 1970 and 1977. These decisions came after heated discussions between the Electricity Department and Treasury. Work on the Tekapo–Pukaki canal began in late 1969.

By mid-1971 the shift from Otematata to Twizel was complete and more than 350 houses and shops and services had been established. By 1972 there were 700 houses and accommodation for 300 single men, and Twizel's population had reached 4,000. In 1974 the population reached a peak of about 6,000 and there were 1,300 houses.

Tekapo B was approved in 1970 and construction began. Because it was built on moraine, and to minimise the length of the penstocks, the powerhouse rested on a free-standing substructure (waterproofed against the raising of the lake to the new level) in an excavated shallow basin. More than 750,000 cubic metres of material had to be removed. A further 160,000 cubic metres was excavated for the intake structure and penstocks. These excavations were begun in May 1971 and took a year. By early 1973 excavation of the station site was complete and concreting had begun.

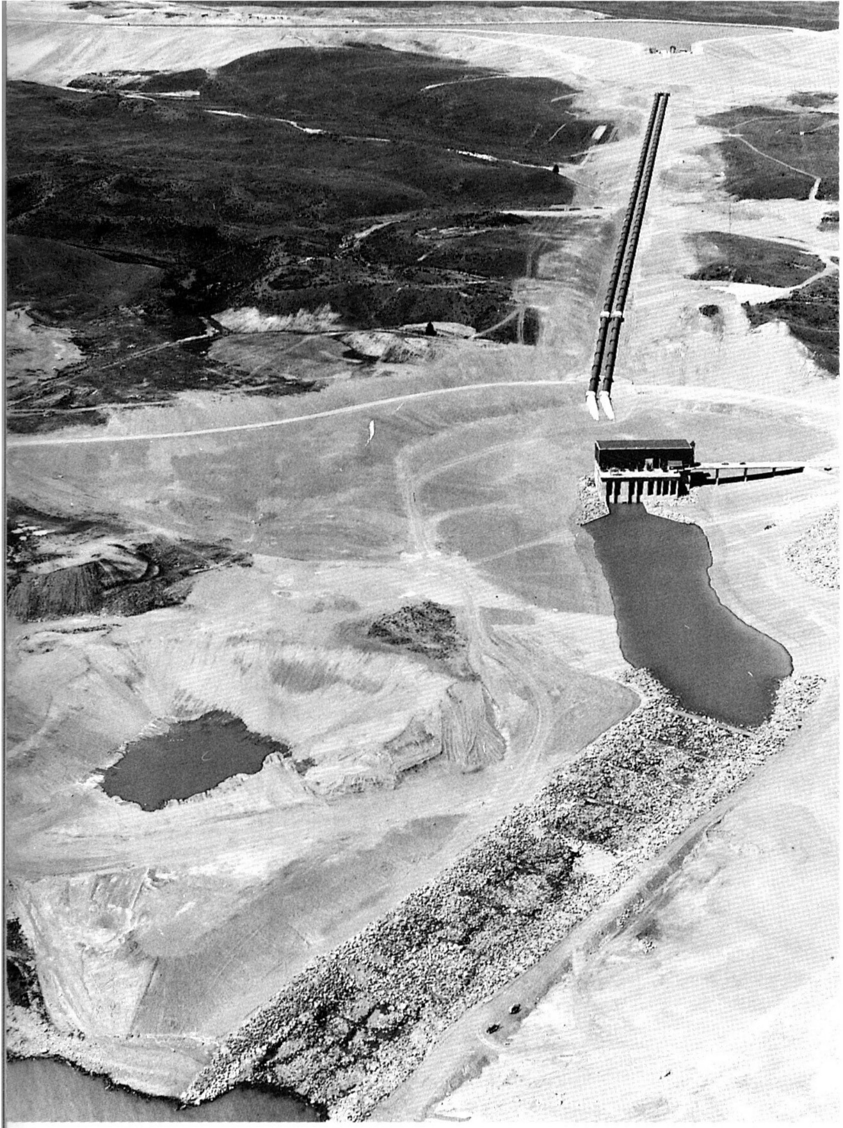
The station, scheduled to generate power in October 1976, now awaited the arrival of the canal from Lake Tekapo, for which 30 million cubic metres of soil had to be moved to form cuttings and to build up gravel shoulders above the level of the surrounding landscape where this was necessary. Half the canal had been excavated by early 1973. By the following year Tekapo B station was half complete and the long penstocks were being erected, while the canal was two-thirds complete.

Authority to start on the Pukaki dam was sought once more in 1970. The Ministry of



Above: The Tekapo B station under construction, looking past one of the large steel penstocks to the powerhouse and lake beyond.

Below: Construction of a shoulder for the 27-kilometre Tekapo–Pukaki canal, the longest of the Upper Waitaki development. This canal begins as the tailrace of the Tekapo A station and terminates at the Tekapo B station beside Lake Pukaki. About 50 million cubic metres of material was moved for canals and other earthworks on the Upper Waitaki development as a whole.

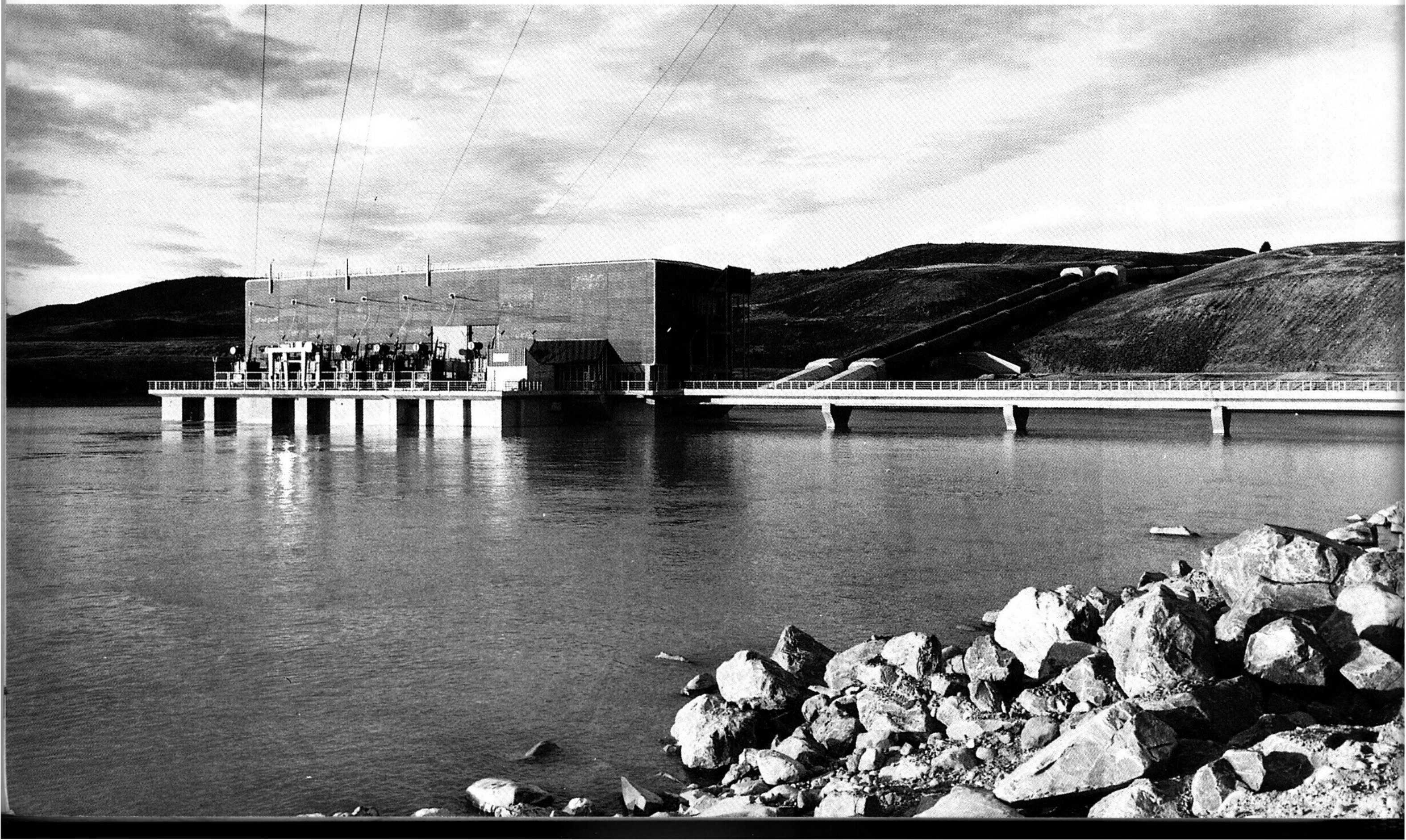


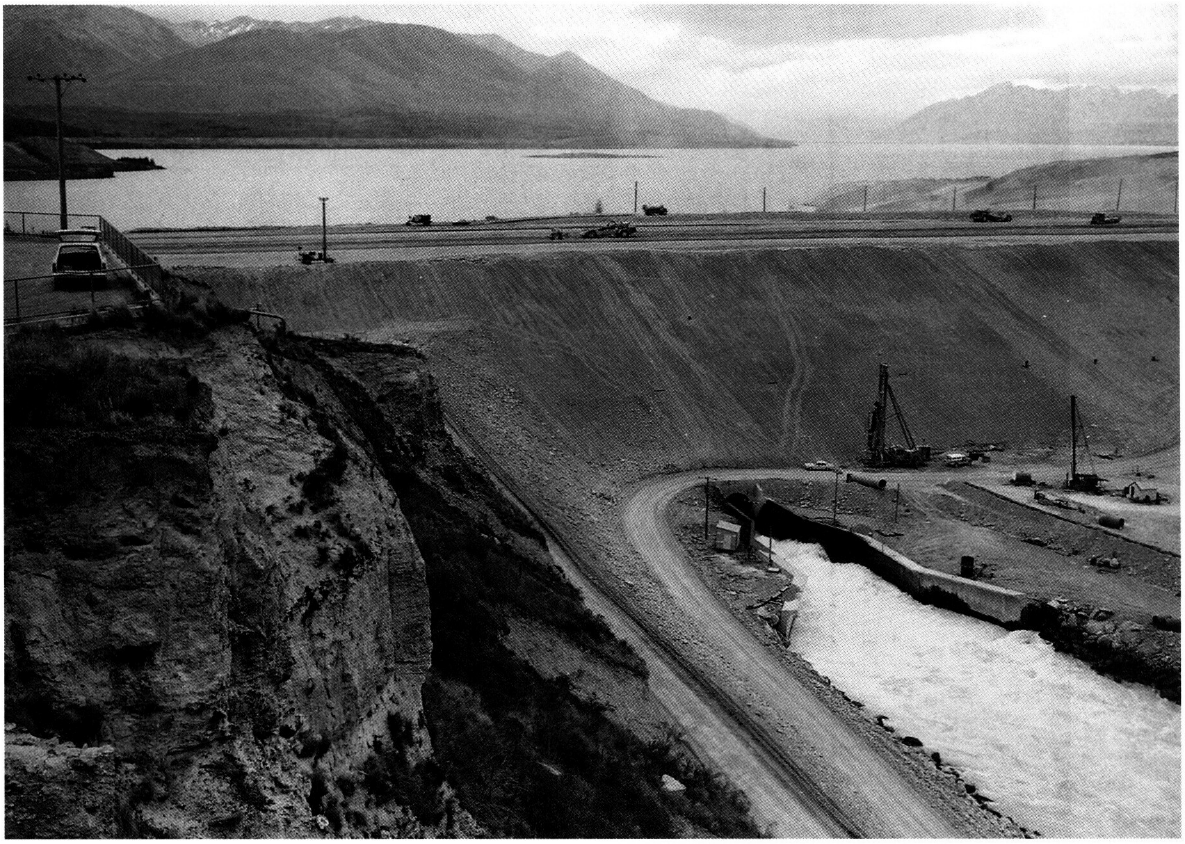
Works now estimated that five years would be needed to build the dam. In December approval to proceed with diversion excavations only was given. As a result, work was concentrated on completing Twizel and advancing the Tekapo canal. In late 1971 more funds were allocated for the dam and work began in earnest. Approval for the next major stage — Ohau A and transmission lines to the Twizel remote-control centre — came in September 1972.

The Pukaki River was diverted in August 1973, foundations were completed early the next year and construction of the dam began. Canal and powerhouse excavation by contractors had begun at the next station, Ohau A, equipment had been purchased for the Tekapo B power station and contracts for Ohau A's generating equipment had been placed.

Left: An aerial view showing the general layout of the Tekapo B station, with the terminal of the Tekapo–Pukaki canal at top and the long penstocks leading down to the powerhouse, which has been built in a basin set back from the lake. The tailrace leads into Lake Pukaki at bottom.

Below: This view from beside the Tekapo B tailrace shows the powerhouse and penstocks entering it from the right. The powerhouse substructure containing the generators and control room was waterproofed because, with the completion of the Pukaki high dam, the lake was raised by 37 metres and the powerhouse site was flooded.





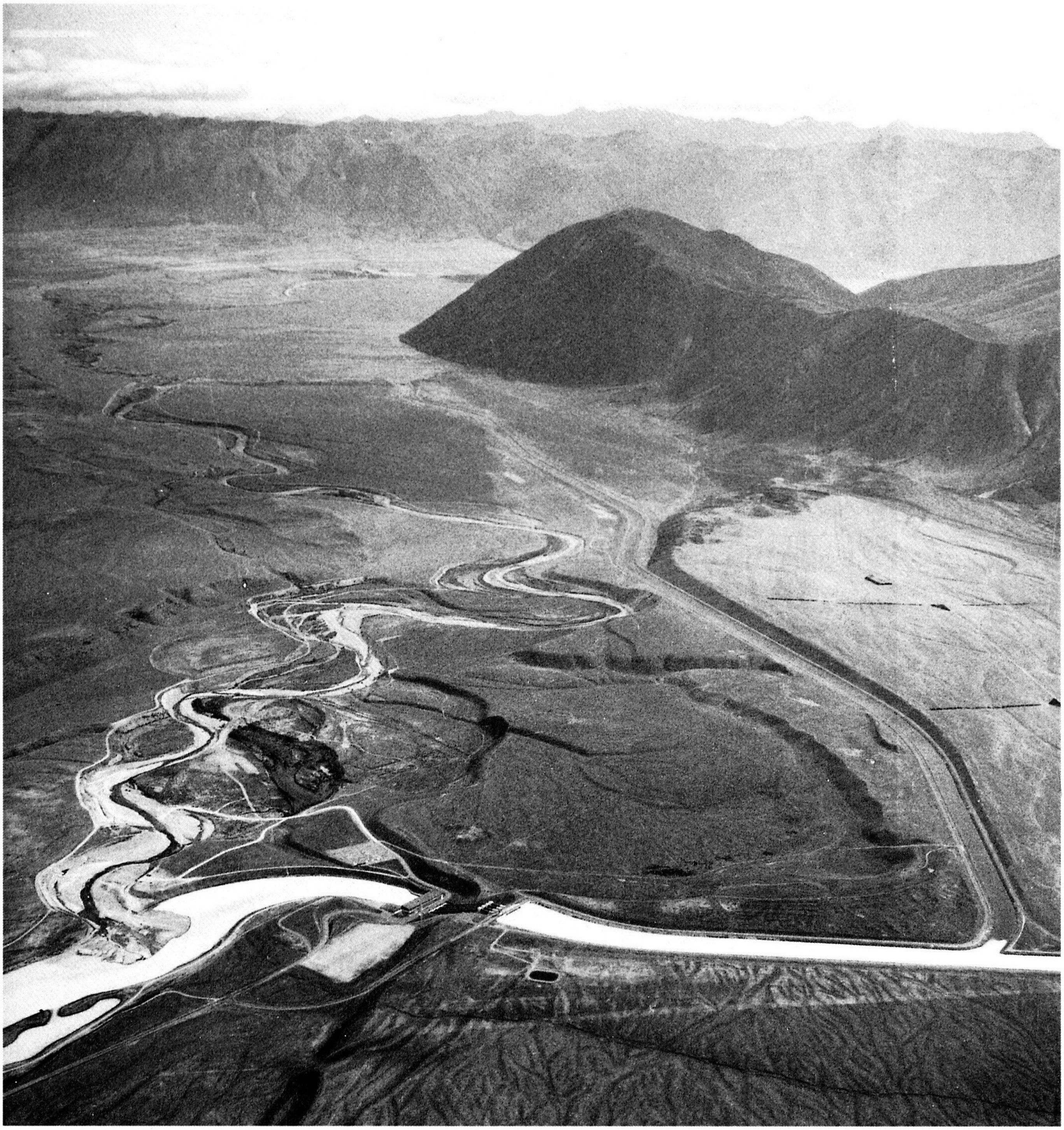
The 'high' earth dam for Lake Pukaki under construction, with the diversion channel underneath. The raising of the lake was very significant in improving the country's hydro-electric storage capacity.

April 1977 had been the target date for power from Ohau A, but by 1975 this was seen to be unrealistic, as work on the station could not begin until skilled labour was released from Tekapo B and Pukaki. The Tekapo canal had required some design changes because of materials encountered, but it was still hoped to commission Tekapo B in 1976. The difficult foundation work at the Pukaki dam had been completed after some delays, and the dam itself was now going ahead.

However, from September 1975 the recruitment of labour and working hours were both restricted, which caused delays on all schemes, especially Ohau A. Work on the Pukaki–Ohau canal almost stopped during 1976. Nonetheless, by early 1976 both Tekapo B and the Pukaki dam were three-quarters completed. The power station had still to await the lining of the canal, which could not be done until the following summer. A limited start was made on raising the level of Lake Pukaki while the dam was still being built.

The delays in completing the dam were to prove critical. An unusually dry year in 1976 meant that water had to be released from Pukaki for power generation and the lake was left well below the desirable operating level for Tekapo B's tailrace, which had to be protected in the meantime. Power had to be sent south via the Cook Strait cable for several months in early 1977 to assist in raising the lake. By this time Tekapo B's two units were almost ready. The first water was released into the Tekapo canal in May 1977, and Tekapo B was commissioned in June. The Pukaki dam was at last completed that year, but the lake was not completely filled until late 1978, and water was not released until the long spillway had been commissioned in January 1979.

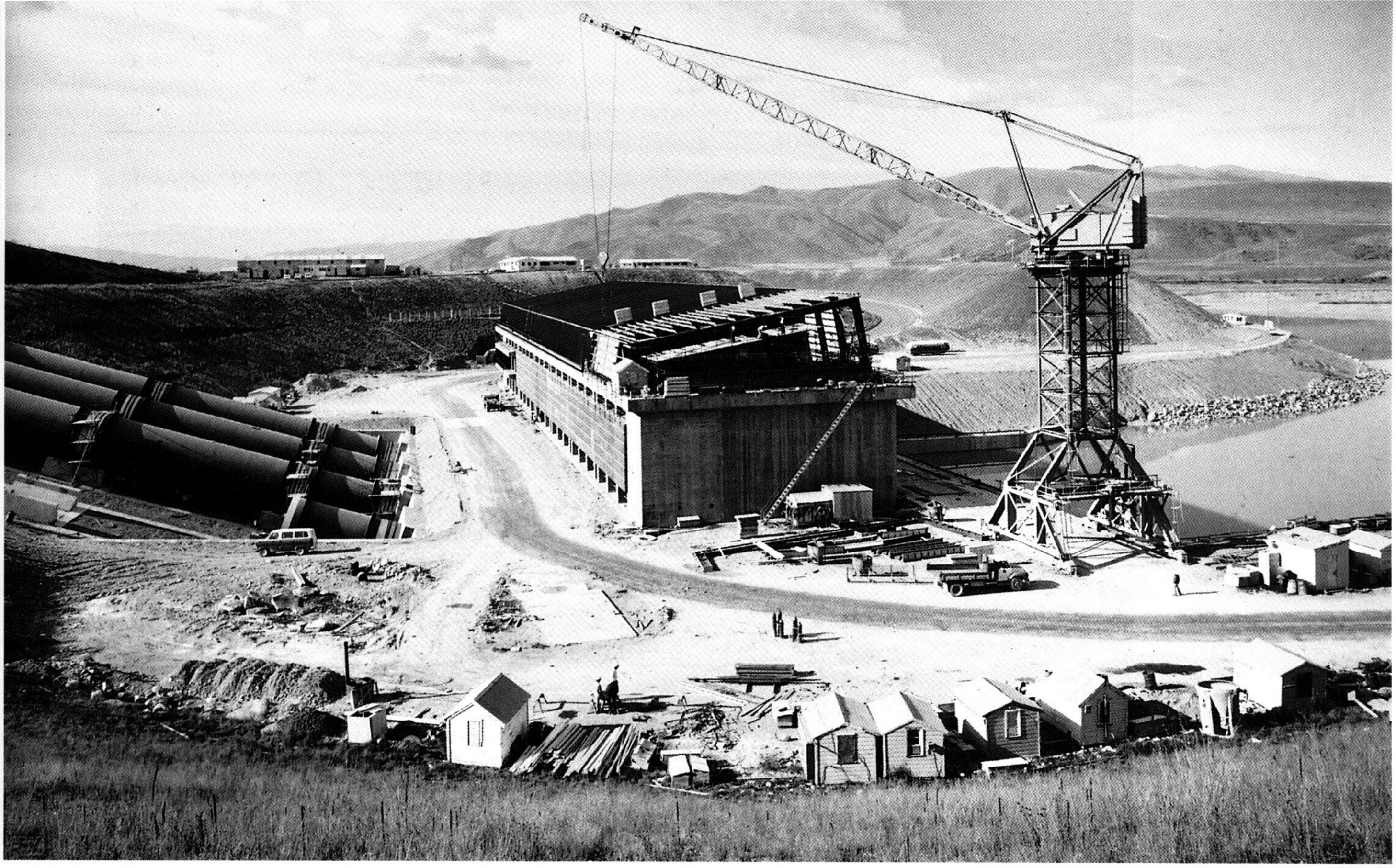
Attention could now turn to the Ohau A power station. By early 1977 it was one-third completed, and by 1978 all the concreting was finished and the four units had been installed. More than 2.5 million cubic metres of material had been excavated for Ohau A. Water was first released into the Pukaki-Ohau canal in March 1979, and the canal from Lake Ohau was filled at the same time. The first two machines were commissioned in 1979, and the last two in mid-1980.



Above: From Lake Pukaki a 12-kilometre canal (from the right) leads to the Ohau A power station (at centre). It is joined shortly before the station by a 8.4-kilometre canal from Lake Ohau (above centre). The different colour of the canal waters can be seen clearly. Water leaves the tailrace of the station and rejoins the Ohau River.

Opposite above: A view of the almost-completed Ohau A power station.

Opposite below: After leaving Ohau A water is dammed by Lake Ruataniwha, a surge reservoir, before being carried by a canal 2.5 kilometres downstream to the Ohau B station, shown here.



During 1977 there was exceptional progress on the Pukaki canal, which was three-quarters finished by early 1978. A major earthmoving effort involving twelve million cubic metres of material during the year ending March 1979 brought both the Pukaki and Ohau canals into use in time for tests and commissioning in 1979 and 1980. 1978 was the peak year for the project as a whole, with 1,750 workers in all on the various sites. The total development was now three-quarters complete. There remained only the dam at Ohau Bridge to create Lake Ruataniwha, the last canal and the Ohau B and C power stations.

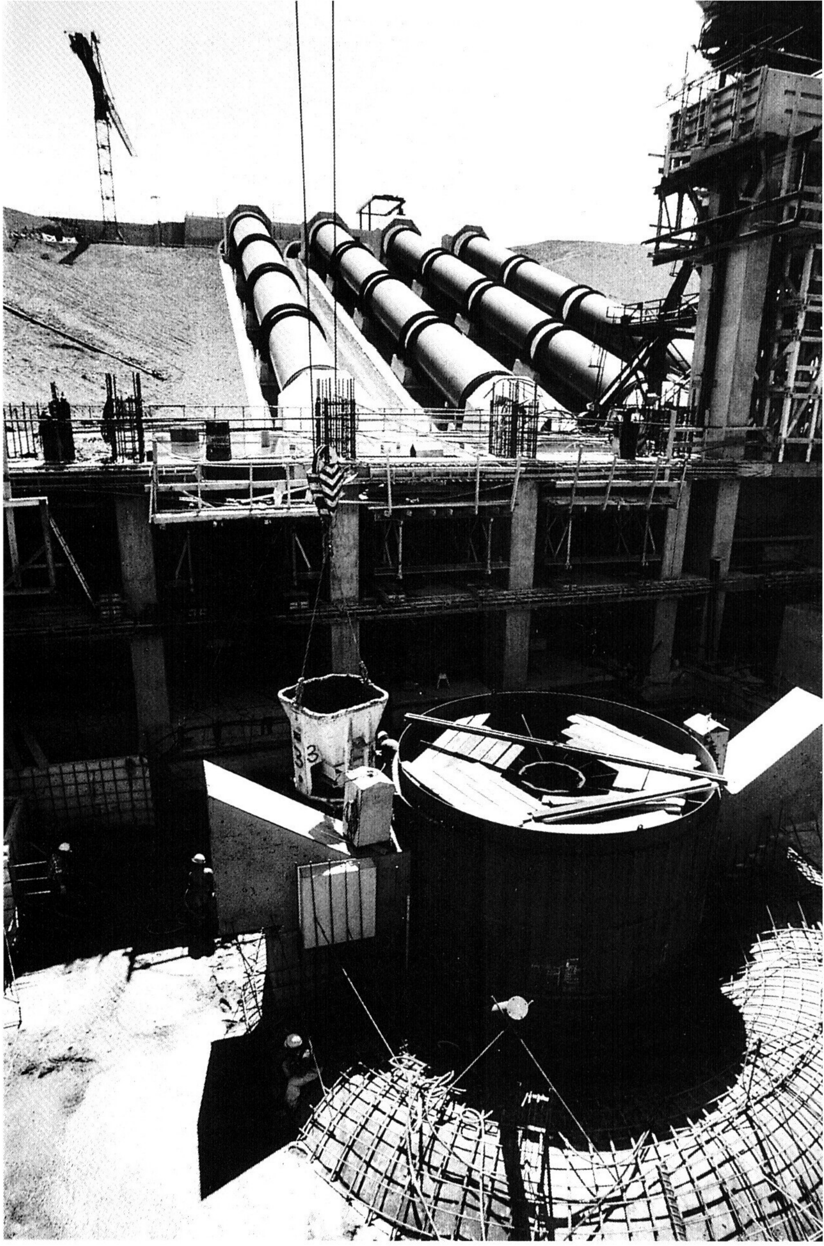
These final two stations had been designed as twins to reduce tendering costs and design work. Approval for Ohau B and C and their associated canal had been given in July 1974, with completion dates of 1979 and 1981. Civil-engineering work at Ohau B began in 1977 and was completed early in 1983. This included the Ohau C canal, which was to receive Ohau B's tailwaters. (Until Ohau C was finished water was discharged over a labyrinth weir that broke up the water as it dropped back into the riverbed.) The installation of turbines at Ohau B began in 1981. The canal was filled and tested in April 1983 in preparation for the commissioning of the first machine in June, and the last machine was in service by March 1984. Excavations for the earth dam for Lake Ruataniwha had been started before 1980, and after the Ohau River was diverted in July 1981 the dam itself was begun. The lake was filled from March 1982.

Work on Ohau C started in 1979; excavations proceeded during 1979–80 and concreting was done in 1981. As the Upper Waitaki work-force wound down, work was concentrated on Ohau C. The station was half complete by early 1982, and by 1984 the penstocks were in place and only mechanical and electrical installation work remained. The first machine was in service in March 1985, and the last by December that year. There was, however, no longer any urgency to commission the plant, as New Zealand now had a surplus of generating capacity.

As the major works neared completion and the work-force was steadily reduced, the future of Twizel, which had originally been planned as a temporary town, became an issue. Discussions with the Mackenzie County Council were on the basis of an 'orderly rundown' in facilities, but the Twizel Community Council wanted the town to continue to exist. The department favoured locating the small number of staff required for the area's remote-control stations at Omarama, and did not wish to be responsible for providing social services at Twizel.

Opposite above: Before the Ohau C station was completed, water was discharged from the canal over this concrete labyrinth weir and back into the Ohau River. The weir serves as a spillway.

Opposite below: After leaving Ohau B the water is carried along the same canal to the twin Ohau C station shown here. The tailrace at left leads into Lake Benmore. To the right can be seen the Ohau River.



A view of the partially completed Ohau C powerhouse, showing the steel penstocks coming down the hill from the end of the canal, and preparations for concreting turbine pits.

By 1982 it was established that the 50 or 60 permanent staff preferred Omarama and the Cabinet Works Committee gave approval in principle for the purchase of land there. Fifty-eight houses were to be moved from Twizel. However, the Twizel community, and nearby runholders who enjoyed its amenities and shopping facilities, were adamant that the town should survive. The Ministry of Works and Development wished to transfer its assets to the Mackenzie County Council, but the county, which considered that Tekapo and Omarama could take over Twizel's servicing functions, was unenthusiastic. The government, however, was anxious to be rid of its responsibilities and an agreement was made in February 1984 for the county to take over the town. In 1986 Twizel, by now a popular holiday centre, maintained a substantial population of nearly 1,300.

The Waitaki River development, which had begun with Benmore, was one of the country's largest hydro-electric projects in one of the most remote areas, and it substantially altered the landscape.[6] The development has provided a number of amenities, including the Mackenzie Hydro Park and Lake Ruataniwha, a water-recreation centre that has been the venue for international rowing regattas. No-one can claim that the Upper Waitaki development left the area unchanged, and some consider that the changes have been detrimental. Its wild tussock wilderness and gravel roads winding down to river crossings have gone, and the Ohau and Pukaki Rivers have been reduced to dried-up beds. Exotic trees have been introduced. But the stark contrast between high country and water and the bold engineering statement inscribed on the land are dramatic in their own way.

CHAPTER TEN

Manapouri

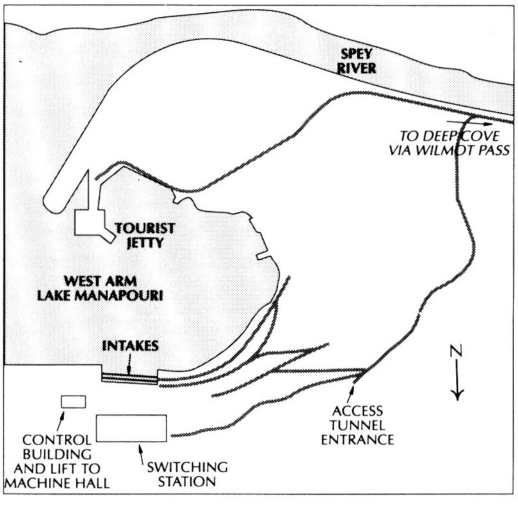
LAKES MANAPOURI AND TE ANAU lie in the very wet, remote and rugged far south-west corner of the South Island, separated by mountains but little distance from the deeply indented West Coast fiords. Manapouri is 583 feet above sea level and Te Anau about 100 feet higher, which gave a potential high head for hydro-electric generation — if a way could be found to get the water down to the fiords.[1]

Most of the area has national park status, with the exception of the eastern side of Te Anau, the southern shore of Manapouri and the Waiau River. Taking the Waiau and Mararoa Rivers into account, the total catchment covers about 2,200 square miles. The shores of Lake Manapouri are bush-clad, as is the western side of Te Anau. The rainfall is very high and spread throughout the year, and this, in combination with the storage capacity of the two lakes, makes for a very reliable water supply. Lake Manapouri, at more than 400 cumecs, has by far the highest outflow of any of New Zealand's lakes.

Hay recognised the potential of the area in 1904. His report considered various possibilities, such as taking Manapouri water via the Lyvia River to Deep Cove or from Te Anau to George Sound. Hay also expressed reservations, which were based on the scenic beauty of both lakes.

In the 1920s A. Leigh Hunt of Wellington and his associates raised a storm of public protest, par-

Manapouri: Constructed 1963–71. Head 580 feet. Water is taken from Lakes Te Anau and Manapouri through intakes at the West Arm of Manapouri, and fed into seven vertical penstocks, 12 feet in diameter, which lead to a powerhouse 700 feet underground. Some 1.6 million cubic yards of underground hard-rock excavation, together with 2.6 million cubic yards of surface excavation, was required. The spiral access tunnel to the powerhouse is 7,000 feet long and 59 feet wide and has a gradient of one in ten. Seven turbines drive 100 MW generators. The first four units were installed in 1969, and the other three in 1970–71. Water is discharged into a large horseshoe-shaped tunnel 5½ miles long, which descends below sea level and then rises to discharge into the sea at Deep Cove in Doubtful Sound. A control structure, 165 metres long and 23.8 metres high, was built at the outlet from Lake Te Anau in 1975. The Mararoa weir and control-gate structure, 770 metres long and 13.4 metres high, was built on the Waiau River in 1976. Total capacity is 700 MW.



ticularly in Dunedin, with a proposal to harness the Bowen Falls and set up a nitrate fertiliser factory in Milford Sound. In 1925 Hunt's syndicate gave up the Bowen River idea and sought rights to Manapouri water instead. Their application was received without enthusiasm by Kissel, who was prepared only to support a licence for a much smaller scheme for Lake Hall, near the South Fiord of Lake Te Anau. He believed that Manapouri should be surveyed by the department, and then offered more widely. Furkert agreed at first, but later supported Hunt's proposal after representations were made to him that only a major scheme would attract investors. Cabinet, which was sceptical of Hunt's ability to carry out such a large undertaking, did not accept the proposal but did ask for surveys and estimates of the cost of such a project to be made.

Furkert and Kissel visited the area in 1925, and assigned an engineer to measure river flows and survey a route from the West Arm of Manapouri to Deep Cove on Doubtful Sound, and another from the Middle Fiord of Te Anau via Lake Hankinson to George Sound. G. P. Anderson made a visit and shrewdly assessed the best locations for dams. The surveyors spent the next three summers in the area, often in the most miserable and wet conditions.

In 1926 Hunt's syndicate was granted water rights, and these were soon assigned to New Zealand Sounds Hydro-electric Concessions Ltd. Anderson made a final inspection in 1929. Accompanied by a geologist, he tramped over to Deep Cove, took a boat to George Sound and walked back to Te Anau via Lake Hankinson. Later that year Anderson produced a report that was to be considered authoritative for many years. He saw very little to be gained by increasing the level of either lake by more than twenty feet. Their 'great natural beauty' could thus be protected.

The company had also engaged in its own investigations. In 1930 an American engineer came to New Zealand on behalf of the American Cyanamide Company. Using Public Works data (which he bought for £250), he reported that a scheme would cost too much. Hunt's company eventually petitioned Parliament unsuccessfully for compensation for work done on promoting the scheme and money spent on geological and engineering reports, which it was argued had considerable value to the government for future planning.

Interest in aluminium smelting was high after the Second World War, and there were a number of unsuccessful attempts to initiate projects based on Manapouri power. In smelting, alumina ore is transformed directly into aluminium by an electrolytic process in baths, or 'pots', containing electrodes, between which very high currents are passed. This consumes a huge amount of electricity. Access to cheap electricity in bulk from a completely reliable source is absolutely crucial for an aluminium smelter.

In 1952 C. W. O. Turner, Engineer-in-Chief of the Ministry of Works, initiated preliminary investigations. For the first time major changes in lake levels were envisaged, and in December 1954 the Director-General of Lands was asked that no land below 690 feet above sea level be sold in the proximity of the lakes. Lake Te Anau, which had a natural range of seventeen feet, might have to be raised by fifteen feet, and Manapouri by close to 100 feet to the level of Te Anau. A Lands Department soil-conservation engineer asked what the effects on Te Anau township would be, and pointed out that any change in sales policy would require public explanation. This was the first shot in a war that was to last nearly twenty years. The State Hydro-electric Department and the Ministry of Works moved quickly to get approval for raising Te Anau, which was given by Goosman in February 1955.

In July 1956 Davenport, in an address to the Southland Progress League, outlined a scheme that was to be followed closely in the eventual project. It involved a high dam on the Waiau River, raising Manapouri to the level of Lake Te Anau, an underground powerhouse and a tailrace under the mountains to Deep Cove. As the possible use of Manapouri electricity for an aluminium industry emerged, so too did polarisation of opinion, with opposition from residents of Manapouri and Te Anau and groups such as the Royal Forest and Bird Protection Society. When the Manapouri Progress Society also expressed deep concern at the proposals, Goosman assured it that actual development was not being considered 'at present', and that other alternatives would be taken into account when final planning took place.

The first definite approach from Consolidated Zinc Pty of Australia, the eventual operator of the smelter, was made to the government and the State Hydro-electric Department in December 1956, after the company discovered a large bauxite deposit in Australia's Cape York Peninsula. In 1958 Turner made the first official approach to the Commonwealth Aluminium Corporation (Comalco), a company registered in Australia and formed by Consolidated Zinc and British Aluminium to develop the bauxite deposits. The company required initially 200 MW of power at a 95 per cent load factor, increasing eventually to a possible 700 MW.

Turner was enthusiastic about the scheme. In reporting to the Commissioner of Works he emphasised the importance of low-cost power in attracting a smelter. He realised that the concept of minimum-cost bulk power supply diverged from existing policy, but emphasised the benefits in overseas funds and the diversification of industry.

Turner went to Australia in May 1959 to follow up a visit by the Minister of Industries and Commerce, to whom Consolidated Zinc had written with more specific proposals. The company was sufficiently interested to begin investigations, but wanted in return to secure all water rights until 1961 and a commitment from the government to negotiate terms. Turner recommended agreement to this, particularly as the company was also investigating other alternatives. In an address to the Southland Progress League in July that year he outlined the potential use of Manapouri power for aluminium smelting by Comalco, and the possible raising of the lake by about 100 feet.

The proposed investigations were announced in September 1959. In November various conservation groups met with Watt to discuss Manapouri and other matters. The meeting recommended the establishment of a watchdog nature-conservancy body. Before the election of 1960 it became National's policy to establish such a body. The Nature Conservation Council Act was eventually passed in late 1962, and a Nature Conservation Council was set up in March 1963. This body immediately became involved in the Manapouri issue, but because of its advisory nature had little real influence on decision-making. The Lands and Survey Department was also monitoring developments on behalf of the National Parks Authority. When the latter sought legal advice as to the rights of the Electricity Department within a national park, its solicitors pointed out that the government would only have to alter the law to force it to bow to its wishes.

Geological surveys continued throughout 1959. The company now sought exclusive rights to the water resources of Manapouri, Te Anau and the Mararoa River. Cabinet reluctantly acceded to the company's desire for an agreement to be ratified by legislation.

The agreement that was finalised in January 1960 allowed Comalco to investigate the potential of the scheme and, provided certain requirements were met, granted the company water rights and the exclusive right to develop and use Manapouri power for 99 years. It was accompanied by an exchange of letters between Consolidated Zinc and the Prime Minister, Walter Nash, who had expressed concern for the preservation of scenic qualities. The company agreed to respect the 'scenic attractions' of the area and to carry out the project in a way that would enhance them. (These assurances were embodied in the Manapouri-Te Anau Development Act 1960, which confirmed the agreement.) In February 1960, after the geological surveys had been finished, Consolidated Zinc engaged the Bechtel Pacific Corporation to undertake the investigations required by the agreement. These proceeded in 1961–62.

In March 1960, while the Manapouri-Te Anau Development Bill was being considered, the Royal Forest and Bird Protection Society and the Scenery Preservation Society presented a petition signed by 25,000 people to the Lands Committee of the House. This asked that the agreement not be validated, that lake levels not be altered, and that the National Parks Act be amended to incorporate safeguards against commercial exploitation.

The Scenery Preservation Society also sent a deputation to see Nash and Watt, but received little response. The petition and other representations were rejected, and the Act passed without division on 7 October 1960.

The Act confirmed the agreement. The company was required to investigate the scheme by December 1962 and develop the first block of 100 MW of power by June 1971. Manapouri could be raised by 93.6 feet to the level of Lake Te Anau, itself raised by 13.5 feet to 676.6 feet above sea level. This level would protect the township of Te Anau, apart from low-lying areas, against flooding.

The availability of finance now became the deciding factor. In November 1960 Kaiser Aluminium of San Francisco became an equal partner in the project. In April 1961 Comalco asked the New Zealand government to guarantee its overseas borrowing, particularly that for hydro-electric development. In July the Minister of Finance signed a letter guaranteeing an American loan, but it soon became clear that funds were not going to be available for either the power scheme or the smelter.

In 1962 all the doubts and problems of the previous years came to a head, and this led to the government itself becoming responsible for the project. Comalco's own position seemed uncertain when Consolidated Zinc merged with Rio Tinto. But the new company retained Consolidated Zinc's rights, and the amalgamation did not affect the New Zealand enterprise. In July 1962 Cabinet decided to allow Comalco to retain its advantageous price even if the government built and operated Manapouri. An officials committee had recommended that the government develop the power. This was accepted by Cabinet, and variations to the existing agreement were negotiated. In January 1963 the company offered to exchange its water rights for the right to obtain continuous power. It was agreed that Comalco should be entitled to 4.8 blocks of 100 MW at 100 per cent load factor, while the Crown could take two blocks at 60 per cent load factor. This would require adding another machine to increase the station's capacity from 600 MW to 700 MW. The Power Planning Committee now recommended that Manapouri's first two units be commissioned by April 1968.

The company was required to use one block of 100 MW by June 1971, and power would be charged at a rate as close as possible to its cost had Comalco itself developed Manapouri. The company agreed to transfer to the Crown the results of its investigations, for which it was to be reimbursed. A Consultative Committee on the Manapouri Power Scheme with wide-ranging powers was established, chaired by Treasury and including representatives from the Ministry of Works, the Electricity Department and Comalco.

The Manapouri-Te Anau Development Act 1963 was also passed without a division in the House. Goosman explained carefully the reasons for exchanging water rights for rights to power, while the Opposition questioned Comalco's commitment to operate a smelter in New Zealand and queried the likely price of electricity. The Act fixed a maximum level for both lakes of 676.6 feet above sea level and a minimum level for Manapouri of 572.5 feet, with the proviso that if the lake was raised above 600 feet the minimum could not be more than 27.5 feet below the raised level.

The construction of the Manapouri scheme was a formidable challenge, highly complex and carried out in conditions seldom encountered. The remoteness, hostile climate and rugged terrain posed considerable transport difficulties and made for extreme working conditions.

The work was planned to be carried out in three stages: first, the intakes, penstocks, a powerhouse with four units and the tailrace tunnel; second, the addition of three further units to bring the station up to its full capacity; third, the Manapouri and Te Anau control works to raise the lakes. The last stage would involve in particular the Mararoa dam, some eight miles down the Waiau River from Lake Manapouri, which would raise Lake Manapouri and incorporate the Mararoa River into the scheme. The intake structure was at the head of the West Arm of Lake Manapouri, with vertical penstock shafts down to the turbines in an underground cavern. The discharge from individual turbines was recombined in a draught tube manifold before entering the long tailrace tunnel leading into Deep Cove.

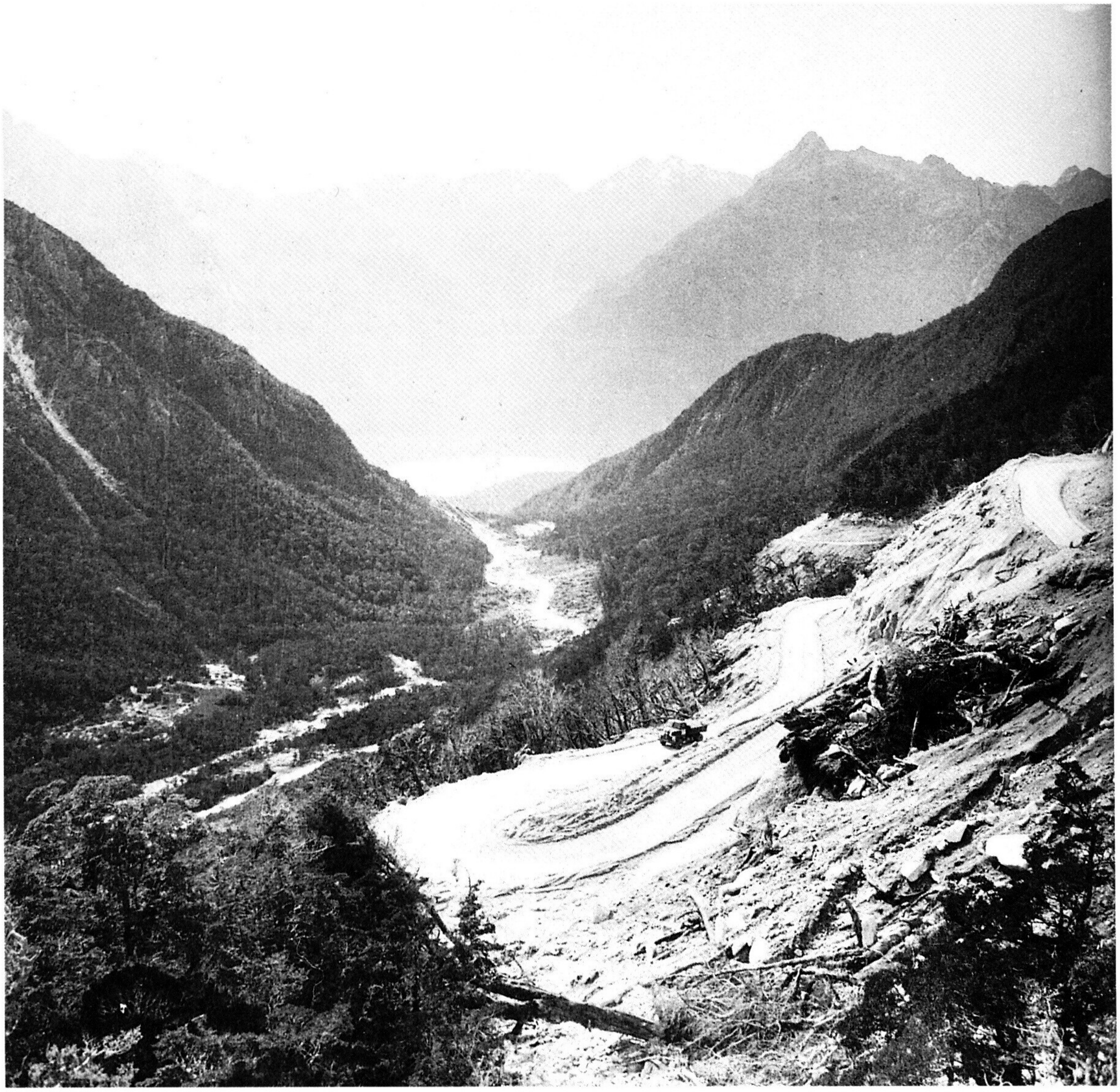
Bechtel, who had been retained as consultants for the project, secured the design and supervision contract in February 1963. There is a story about a Bechtel senior engineer who wanted detailed aerial photogrammetric surveys done, and did not believe the Ministry of Works when told that this would not be appropriate. The ministry insisted that ground surveying was necessary. After visiting the site he apologised, saying that he had never before worked in country where the trees concealed the topography!

In July 1963 a consortium of the Utah Construction and Mining Company and two local firms was awarded the crucial contract for the long tailrace tunnel and the Wilmot Pass road. Utah also got the contract for the powerhouse cavern and associated works, and for the installation of the initial four units, and was thus the major construction contractor on the project. The former passenger liner *Wanganella* arrived in August, and was moored in Deep Cove for six years as accommodation for the 500 men working on the tailrace tunnel and the road.

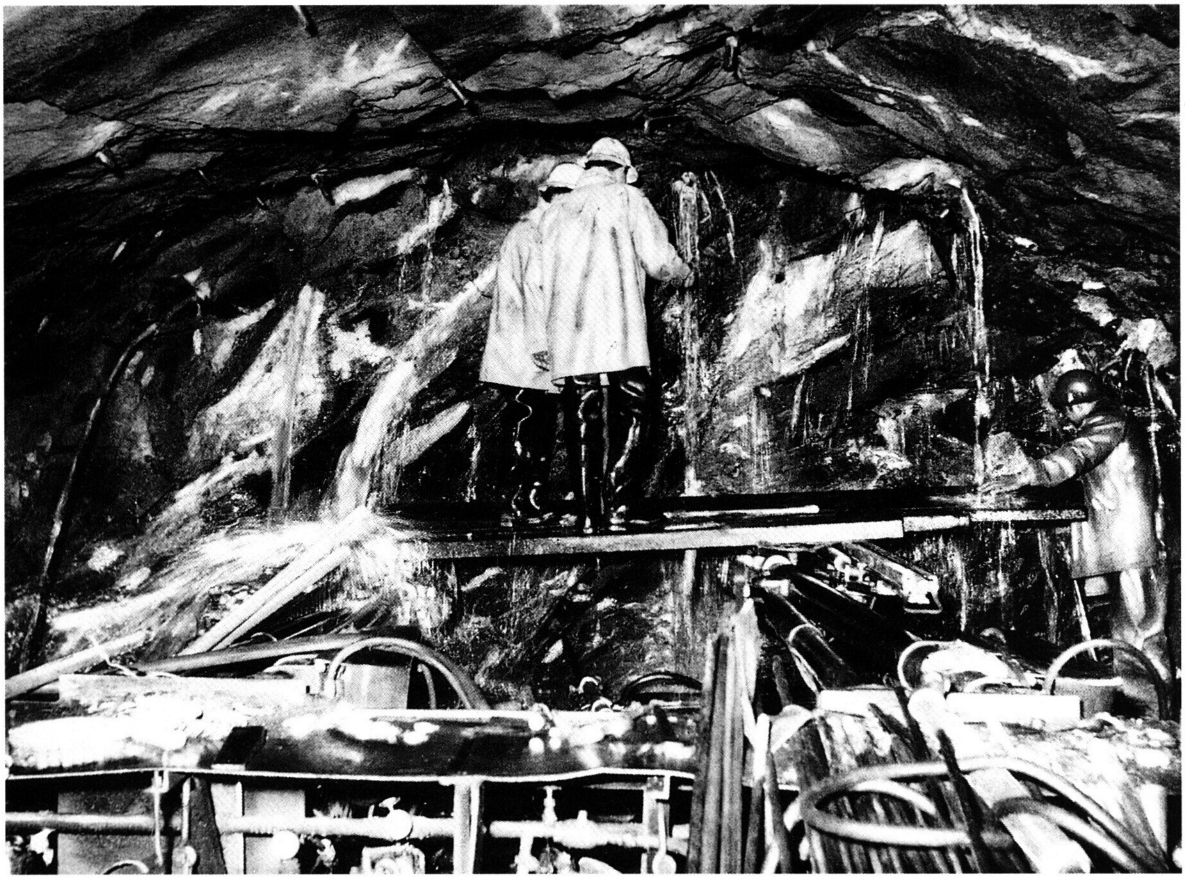
In October 1963 Utah began work on the road needed to take the heavy power station plant into West Arm from the deep-water anchorage in Doubtful Sound. This was a cheaper option than upgrading the Bluff to Manapouri road and transporting machinery across the lake. The road would be twelve and a half miles long and run through some very rugged and precipitous country and over Wilmot Pass, which was 2,200 feet high. Building the road was a formidable task carried out in incessant rain over swampy ground on the flat and sheer rock faces on the mountains, but was completed in two years. The road alleviated the extreme isolation felt at Deep Cove and improved conditions considerably.

The tailrace tunnel, the crucial job in terms of the project's overall schedule, was five and a half miles long and 30 feet in diameter. From the powerhouse at West Arm it dropped about 700 feet below lake level to a depth of 135 feet below sea level before rising to discharge into Doubtful Sound. The tunnel was begun in February 1964 and was driven full face, largely from the Deep Cove end. The contract stipulated that it be holed through by September 1966.

A hydraulically operated sliding floor said to be the largest in the world was used. This was made in four sections that moved forward as the tunnel advanced. Both the 45-ton three-tiered drilling jumbo that bored the holes for blast shot, and the mucking machines that removed the spoil after blasting and cleaning down and loaded it onto electric trains, were mounted on rails on the floor. By the end of 1964 nearly three-quarters of a mile of the tunnel had been driven. After the lowest point was reached at the end of 1965 increasing inflows of water became a major problem. More than a mile was driven that year.



Building the 12½-mile access road over the rugged Wilmot Pass from Deep Cove in Doubtful Sound to the West Arm of Lake Manapouri was a formidable task. It was cheaper to bring heavy equipment over the pass from a deep-water anchorage in Deep Cove than to take it across the lake.



The Manapouri tailrace tunnel, which ran 5½ miles from the underground powerhouse to Deep Cove, was the most crucial and difficult part of the scheme. Serious delays were caused by broken rock and large quantities of water. A 45-ton three-tier 'jumbo' (working platform), shown in the foreground, was used for driving the tunnel. Water gushes from cracks in the rock face. Tie-rods stabilising the broken rock can be seen in the ceiling.

Conditions became very difficult in 1966, and in February the contract was extended to January 1968. Progress was slowed by the presence of water, and much grouting and steel-arch support was needed because of the broken rock. In that year only three-quarters of a mile was driven, making a total of three miles. Because of the difficulties Utah Construction sought to terminate the work. After much discussion, the method of payment was revised in October 1966 and the contract was again extended to July 1969.

Better progress was made in 1967 with less water encountered, but arches were still needed. One and two-thirds miles were driven that year, and the tunnel was at last holed through on 22 October 1968, more than two years late. J. R. Hanan, the Minister of Justice and a Southland MP, fired the last shot in the tailrace tunnel — and blew everyone's safety helmets off! The average weekly driving rate had been 124 feet, with the record 310 feet. The tunnel was completed in August 1969 after being lined with concrete.

The third major job was the contract awarded in December 1963 to Morrison-Downer-Fletcher to construct a 7,000-foot road tunnel in the form of a spiral from West Arm to the underground powerhouse. This was started in March 1964, and a year later was three-quarters complete, but well over the estimated costs. Here, too, water slowed progress; the downward slope of the tunnel added to clearance problems.

A major row about redundancy provisions broke out just as the contract for the access tunnel was being completed in 1965. The contractors for the powerhouse cavern, Utah Construction, would not guarantee the re-employment of the tunnellers, and did not want to engage men until after the award application hearing in mid-September. The Ministry of Works, in its supervisory capacity, was concerned to retain a workforce; Shand organised interim forestry work in the area for those who wanted it. The tunnellers went on strike nevertheless, and on 30 August Morrison-Downer-Fletcher terminated their contract with 44 feet of the tunnel unfinished. Union representatives, fearing the loss of all redundancy pay, quickly agreed to supply labour for the final cleaning down of the tunnel, and to maintain essential services until Utah took the work over. The access tunnel was finished in November 1965, a year behind schedule. This caused the completion date for the powerhouse to be deferred by a year.

The trade unions engaged in a fierce battle for coverage, first at Deep Cove and then at West Arm. This dispute worried the contractors because work stoppages were difficult to handle when union jurisdiction was not clear. It was hard enough to keep the work-force content, given the conditions they had to work under, and labour turnover was high. The New Zealand Workers' Union had traditionally been the site union for Ministry of Works hydro-electric projects, but the Labourers' Union also sought coverage at Deep Cove. The Federation of Labour unexpectedly supported the Workers' Union, which won the right to cover the entire Deep Cove workforce. A resident union official was appointed, an important factor in maintaining a good working relationship.

The Workers' Union wanted to achieve the same position at West Arm. Shand met with the Labourers' Union, which was still very angry about the Deep Cove decision, and it was agreed that the Arbitration Court should decide, with the Department of Labour to conduct a secret ballot if necessary. A ballot was duly held in which the Workers' Union gained majority support, but the problem reappeared with the letting of tenders for the powerhouse, which brought in both new contractors and skilled tradesmen. Utah Construction, the powerhouse contractor, applied to the Arbitration Court for exemption from award provisions. Tom Skinner, the President of the Federation of Labour, proposed that the federation negotiate a composite agreement with individual unions. The contractors were willing to talk to Skinner but wanted an undertaking from the government that they would be compensated for any pay increases.

In November Cabinet accepted that negotiations for a composite agreement were necessary for the project to go ahead. These duly proceeded, the contractors were on the job before the end of November, and by February 1965 the Workers' Union had become a party to the agreement and had its officials on site. The project's wage workers had already formed a West Arm Combined Unions Association, which appointed a job committee to negotiate with Utah's project manager, but this was not as effective as the single union official at Deep Cove, and the four years that followed were never quite free of problems.

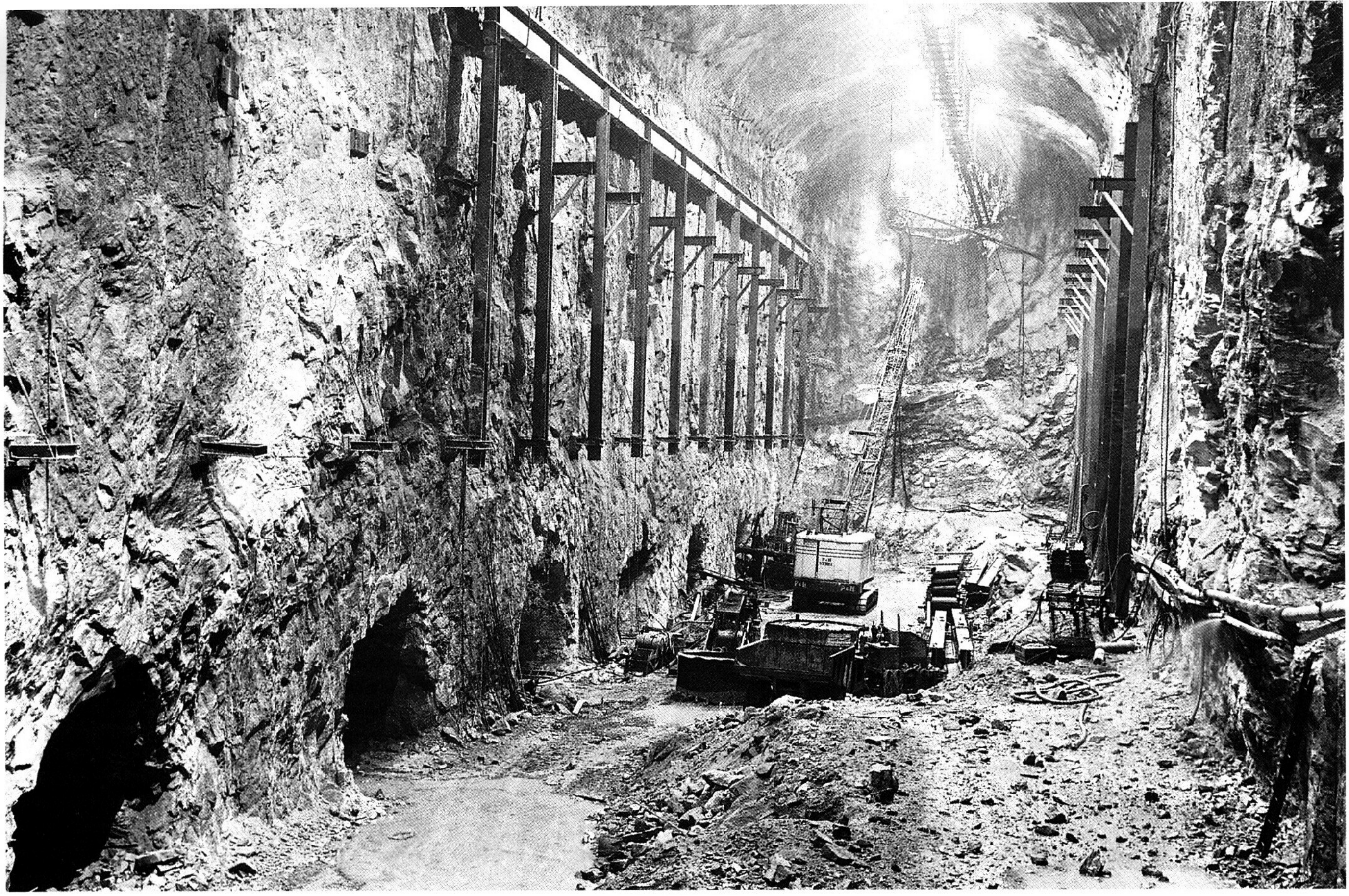
The village for permanent staff was built at the Manapouri township while transmission line routes were pushed through by contractors under Bechtel's supervision. In June 1966 the Electricity Department began to erect the transmission lines, an engineering feat in itself. The route traversed high altitudes, had long spans across mountain valleys and was subject to strong winds, ice and salt corrosion at the Deep Cove end. Of the 106 miles of line between West Arm and Bluff, 29 miles lay over mountainous bush-clad country, the roughest stretch being the first miles from West Arm over the 3,500-foot-high Turret Range to the Percy and Grebe Valleys. A road could be pushed through from the Grebe Valley to Monowai over the Borland Saddle in the Hunter Mountains, but the first part of the line was too rugged. Some 50 miles of roads were put in.

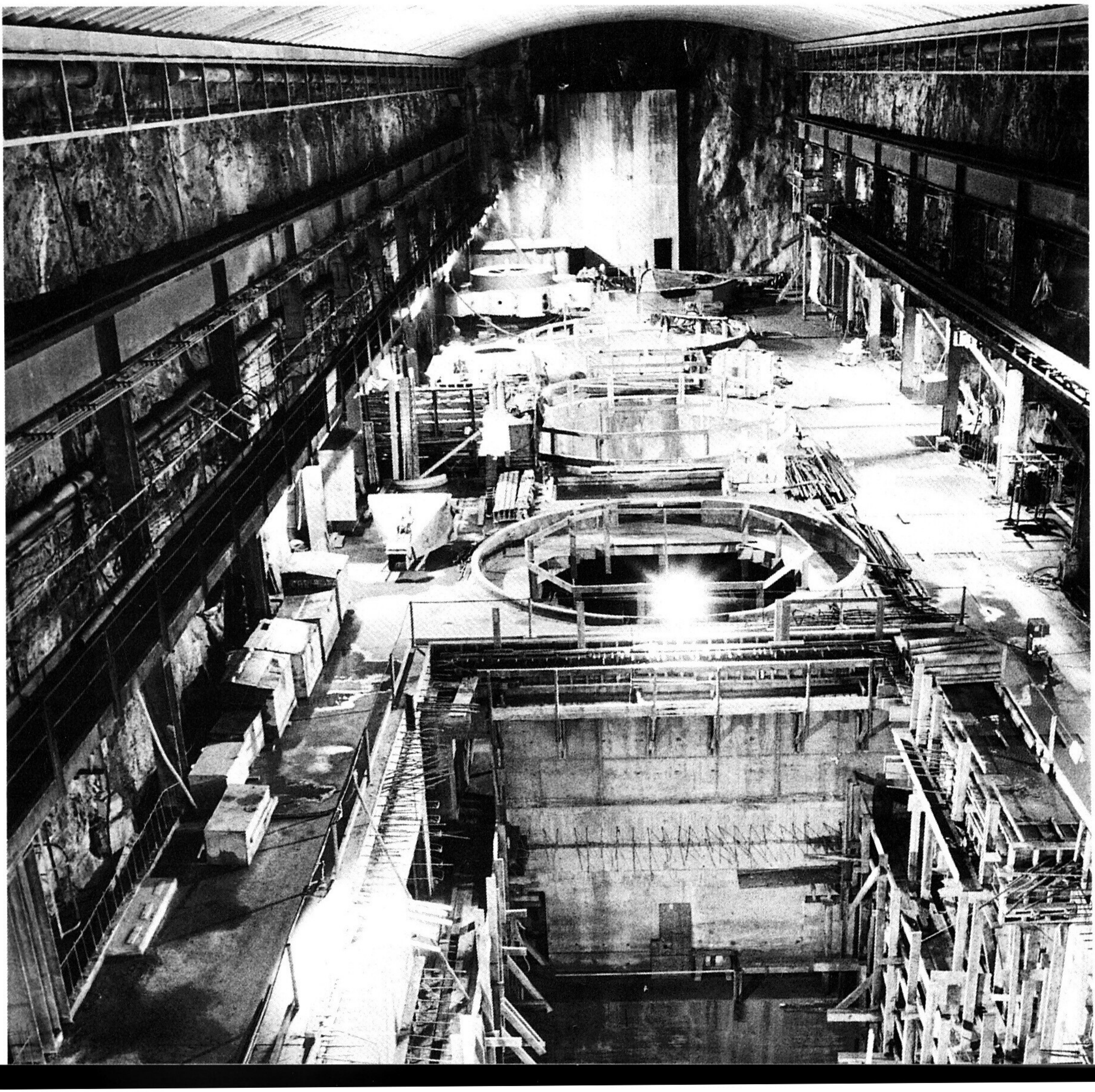
In June 1965, after delays caused by the failure of contractors to tender, Utah won the contract for the underground powerhouse and its associated surge chamber, penstocks, cable shafts and elevator shaft, and for the installation of the first four units, together with the work on the surface at West Arm on the intakes, switchyard and control building.

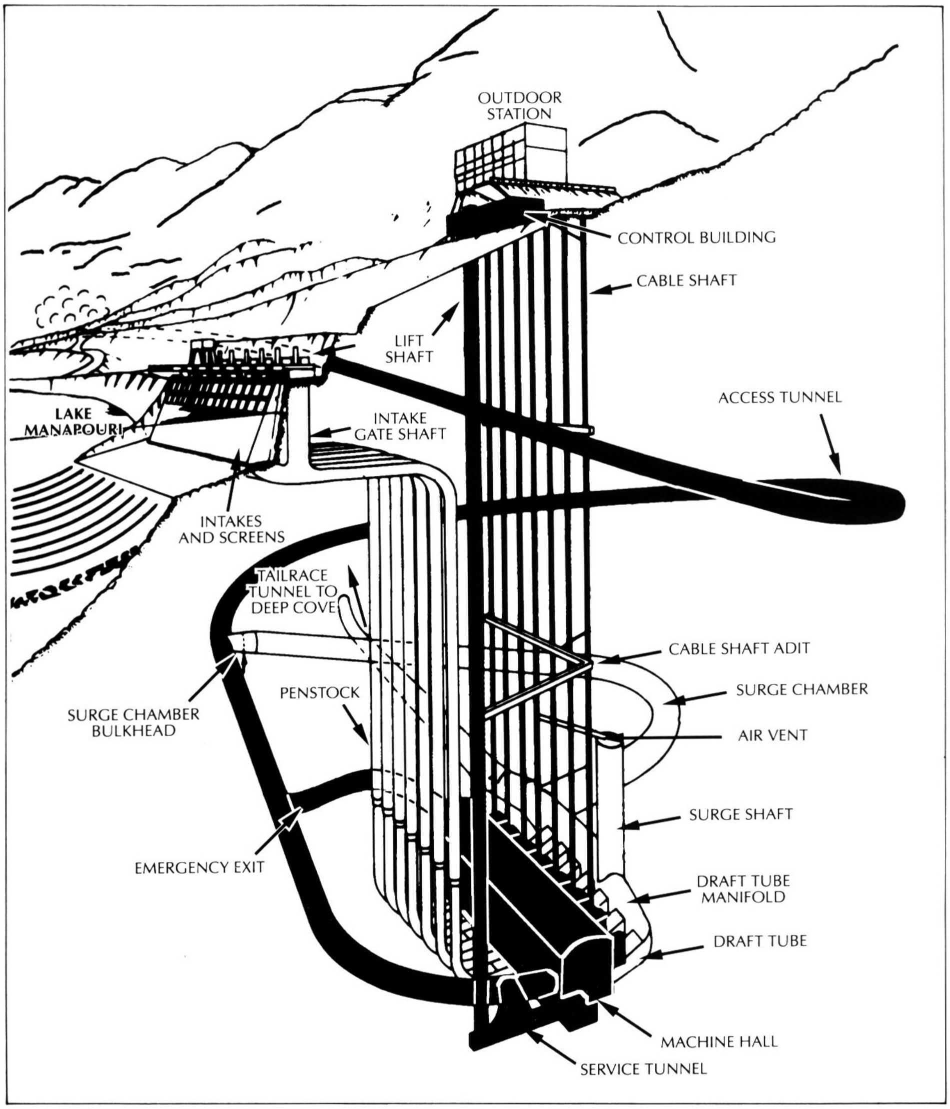
The powerhouse, which was hewn out of solid rock, required complicated excavation and tunnelling. The excavation of the main cavern, 362 feet long, 59 feet wide and 128 feet high, was begun in 1966 and nearly finished by the end of 1967. This involved creating a tunnel along the roofline, which was then widened to the full width of the cavern and excavated downwards in steps to the floor.

In 1968 the control building above ground was begun, the tailrace tunnel was completed and the first four machines were installed. A particularly delicate job was the removal of the rock barrier at the intake by very careful submarine blasting. The first power was generated on 14 September 1969. Two machines were commissioned that month, and the other two making up the first stage in October.

At this time Comalco was negotiating with Japanese interests for a share in the smelter ven-






OUTDOOR STATION
CONTROL BUILDING
CABLE SHAFT
LIFT SHAFT
ACCESS TUNNEL
LAKE MANAPOURI
INTAKE GATE SHAFT
INTAKES AND SCREENS
TAILRACE TUNNEL TO DEEP COVE
CABLE SHAFT ADIT
SURGE CHAMBER
SURGE CHAMBER BULKHEAD
PENSTOCK
AIR VENT
SURGE SHAFT
EMERGENCY EXIT
DRAFT TUBE MANIFOLD
DRAFT TUBE
MACHINE HALL
SERVICE TUNNEL

Above: The Manapouri powerhouse.

Opposite above: The powerhouse was situated in a cavern some 700 feet underground, which is shown here being excavated in October 1967. First the access tunnel was driven down to the site, and then the cavern was excavated downwards from the roofline. To the left the penstock tunnel openings can be seen.

Opposite below: By October 1968 the powerhouse floor had been built and turbines and generators were being installed. The first four machines began generating in late 1969, and the last three in mid-1971.

ture. In September 1969 an agreement was signed between Comalco, Showa Aluminium KK and Sumitomo Aluminium, and construction of the smelter at Tiwai Point began that year. The last three generators were installed in 1970 and commissioned by the middle of 1971, three months ahead of schedule. The addition of the seventh 100 MW unit created higher than anticipated tunnel-discharge losses, which, in conjunction with the decision to keep Lake Manapouri at its natural level, effectively made this unit a spare and has limited peak power to approximately 600 MW.

The first aluminium was produced at Tiwai Point in April 1971; by October Manapouri was providing full power to the smelter and Bechtel handed the station over to the Electricity Department. The project had taken eight years to complete.

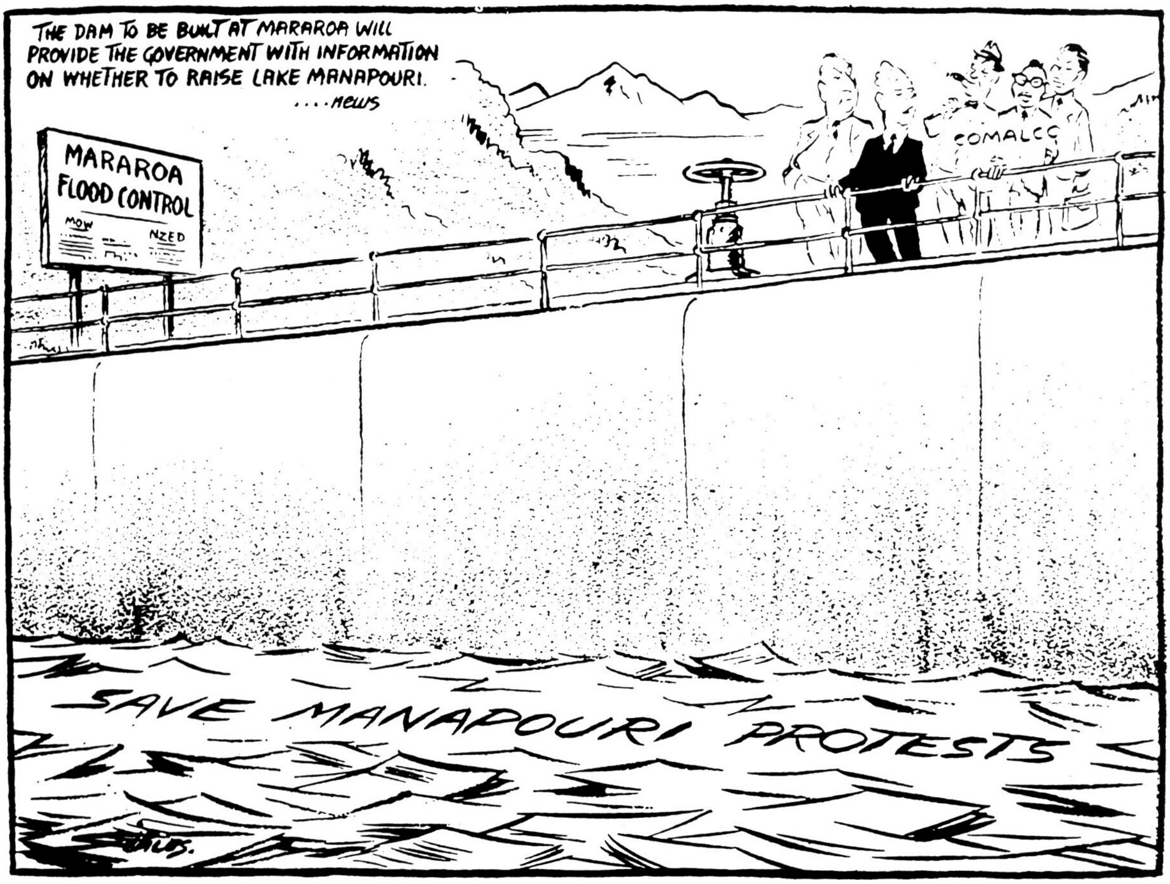
It had not been without cost, despite carefully laid-down safety procedures and frequent visits by inspectors. High labour turnover was a problem, and there were considerable hazards inherent in the project. All too often highly experienced men were injured or killed in a moment of disregard for safe practices. At other times there were accidents that could not have been anticipated. Basic first-aid and nursing facilities were available on site, but any serious injury required evacuation by air to Invercargill's Kew Hospital. A total of eighteen men died in accidents during construction. Tunnelling was particularly hazardous. Some workers were struck by the trains moving material in the tunnels, others by rock falls or during drilling operations. The most unusual death was that of a worker who was accidently blown up as he hastened to catch the afternoon launch from West Arm to go to the Riverton races while blasting was occurring on the Wilmot Pass road. In 1967, when there were more than 1,000 men on site, there were 84 serious accidents at Deep Cove, 123 at West Arm and sixteen on the transmission line roads.

The vexed issue of lake levels had become a focus of discussion by 1965, when investigations by Bechtel indicated that the original proposal to raise Manapouri to 676.6 feet was not technically feasible. Without raising the lake from its natural level of 583 feet, the station's capacity would be 630 MW and the available energy 4,905 GWh. If the lake was raised to 610 feet, the capacity would be increased to close to its maximum potential at 690 MW and the energy to 5,127 GWh; if the level was 620 feet, the available energy would be 5,245 GWh. In terms of the 1966 agreement (for 680 MW and 5,254 GWh), 610 feet would give enough capacity for both partners but would leave the Crown short of 127 GWh of energy. It would be possible to supply Comalco with the necessary power without raising the lake at all, but the government would thereby lose 60 MW and 222 GWh. Mackenzie, the General Manager of the Electricity Department, wrote to Comalco in September 1965 stating a preference for a level of 600 feet. While raising the lake would bring only small percentage increases in available energy, the most important factor from Comalco's point of view was that a continuous supply of electricity for the smelter be absolutely assured. This would necessitate considerable safety margins in water storage. Comalco pointed out that the government had already agreed to the higher lake level. It would not accept a change of plan for reasons of cost or public opposition; only technical problems would suffice.

During 1966 the cost of the project was reassessed. Not only was the contract price for the powerhouse very much higher than the original estimate, but the contractors were also seeking recompense for additional costs beyond their tenders, particularly for the tailrace tunnel contract. Comalco, for its part, was concerned about both delays and increased costs, which would affect the price eventually paid by the company for power, while the government wanted a quick return on its capital investment by using cheaper Manapouri power from the final three units to postpone the Upper Waitaki development. After receiving reports from consultants and having discussions with Comalco, Shand announced in July 1966 that the level of Lake Manapouri would not now exceed 620 feet, and would probably be between 600 and 610 feet.

The 1963 agreement was therefore amended in 1966. The government would now install immediately seven units planned for Manapouri. The Crown would be able temporarily to get additional power above the two blocks that had already been allocated to it until 1976. Comalco had the right to 2.4 100 MW blocks until December 1972 and then three blocks until September 1976. Part of the Crown's two blocks of power could be made available to Comalco after June 1986. The cost of power was to be based on the capital cost of the Manapouri project itself. This was spelt out in the agreement, which recognised the additional costs that had been incurred without changing the principles of the 1963 agreement. This assured the company as to the price of power during the smelter's development period, and Comalco finally made a public commitment to establish the smelter at Tiwai Point.

Manapouri soon became the largest conservation issue in New Zealand's history. Concerted opposition and a questioning of the need to raise its level at all had arisen by the late 1960s. The graphic example of Lake Monowai, which had been raised by only eight feet, lay close at hand. Studies of the impact of raising the lake suggested that $6.5 million would be required to clear bush around the lake edges. Comalco considered this too high and suggested amending the Act. The Nature Conservation Council met at Te Anau in February 1967 and reaffirmed that Manapouri should not be raised. In May Dunedin's District


THE DAM TO BE BUILT AT MARAROA WILL PROVIDE THE GOVERNMENT WITH INFORMATION ON WHETHER TO RAISE LAKE MANAPOURI. ....news
MARAROA FLOOD CONTROL
MOW
NZED
COMALCO
SAVE MANAPOURI PROTESTS
SCALES.

"Perhaps that'll hold them for a while!"

By the late 1960s opposition to raising Lake Manapouri had intensified and eventually all plans to raise the lake were abandoned. The proposed Mararoa dam was the crucial element in raising the lake.

Sid Scales, *Otago Daily Times*, 24 September 1971

Commissioner of Works visited the area with Comalco's Chief Power Engineer. They found that ground clearing would be a tougher task than had been expected, and suggested that flexibility in the standard to which this was done would decrease costs. A confidential Ministry of Works report in July confirmed that there would be much damage if the lake was raised, and suggested that other ways to meet the government's commitment to Comalco should be explored.

The country's newspapers were by now full of protest, and prestigious groups such as the Royal Society joined with the other organisations that had long been vocal. On the other side, the chairman of the Supply Authorities Association, which supported the principle of producing power as cheaply as possible, sent a circular to member authorities deploring the silence of electricity consumers in the face of the conservationists. Others anxious for development, such as the Southland County Council and Otago Federated Farmers, favoured raising the lake, while the Oamaru Borough Council urged development of the Waitaki Valley instead. National undertook to set up a commission of enquiry if it was returned to power in the 1969 election.

Late in 1969 an important figure passed from the scene when Tom Shand died in office. He had played an impressive and practical part throughout, always supporting his department in public but constantly asking questions and concerned that the correct conclusions were reached. His very direct role in resolving disputes as Minister of Labour was perhaps even more important for Manapouri than his actions as Minister of Electricity.

Opposition to raising the lake now intensified. In October 1969 the Fiordland National Park Board had convened a public meeting in Invercargill at which it was decided to form a Save Manapouri Committee. In January 1970 a meeting in Wellington resolved to form branches of the Save Manapouri Committee throughout the country. In preparation for the next stage of development, Cabinet in the same month appointed a ministerial committee to report on the raising of the lake, and announced that a commission of enquiry would be established. An officials committee comprising the permanent heads of Electricity, Works, the Department of Scientific and Industrial Research, Treasury, Lands, Tourist and Publicity, and the Forest Service, and the Solicitor-General was also formed. The Cabinet Committee reported in April, setting out the effects on generation of various lake levels, Comalco's rights under the agreement, the consequences of raising Lake Manapouri, and the cost of not doing so.

The Save Manapouri Campaign held a conference in Wellington in March 1970 that was attended by representatives of more than 50 organisations. It exerted much influence and tapped a very wide cross-section of community and pressure groups. An extensive publicity campaign was conducted using pamphlets, news media releases, protest marches and public meetings. In Parliament the Labour Opposition became increasingly embarrassed about its role in the original negotiations, but could not deny that the agreement and legislation of 1960 had envisaged full development, and that the 1963 Act had passed without dissent.

In April 1970 the promised commission of enquiry was set up. Its terms of reference included the government's obligations to Comalco, and the economic and environmental implications of various levels of both lakes. Comalco and a range of government departments, including the Electricity Department, gave evidence. The bulk of non-government and individual submissions were against raising the lake. The commission listened to submissions for three months. Its report in October 1970 resolved nothing, for it confirmed that 'the Crown is contractually bound to Comalco to raise the level of Lake Manapouri to 610 feet El[evation]. or possibly, dependent on current engineering investigations, to 620 feet El'.[2] Any abrogation of the agreement might well entitle Comalco to considerable damages or compensation. The commission recognised that raising the level would have detrimental effects on the lake but considered that shoreline clearance was feasible — at a cost. It also recommended that agreement be reached to drop Lake Te Anau's proposed maximum level slightly to safeguard the township. Meanwhile the government and Comalco met in late November 1970 to discuss how raising the lake could be avoided.

A second huge petition, organised by the Royal Forest and Bird Protection Society and comprising 265,000 signatures, was presented in December 1970, having been deferred until the commission had reported. A parliamentary select committee was established to hear evidence on this and other petitions. In June 1971 it recommended to Parliament that the petitions should receive 'favourable consideration', but this was qualified by a suggestion that the Mararoa dam should be built with a wide enough foundation for a higher structure, but without the lake actually being raised! The select committee also argued that any decision to raise the lake should be made by Parliament itself. By this time a temporary rock weir had been built to control the outflow from Lake Manapouri.

In September 1971 the government announced that the lake would not in the meantime be raised. But the legal obligations to Comalco remained. In November a large march in Invercargill protested against government inaction in renegotiating the agreement with Comalco. Agitation continued into 1972. With an election approaching, the Labour Party reversed its previous policy and undertook not to raise the lake if it became the government.

Meanwhile a dry year had highlighted the problems of changing lake levels. The lake fell below its previously record low level and slumping of the shoreline occurred. In October and November 1972 a Lakes Manapouri and Te Anau Liaison Committee representative of local conservation groups and government departments was established.

The Labour Party's widely publicised pledges rapidly became government policy upon its election. The Manapouri issue had swung votes to Labour, especially in the far south, where National lost both the Awarua and Invercargill seats. Tom McGuigan, the new Minister of Electricity, stated on the day of the first Cabinet meeting in early December that the lake would not be raised. The Cabinet Works Committee recommended on 29 January 1973 that the lake should not be raised, and that there should be consultations about its operating levels.

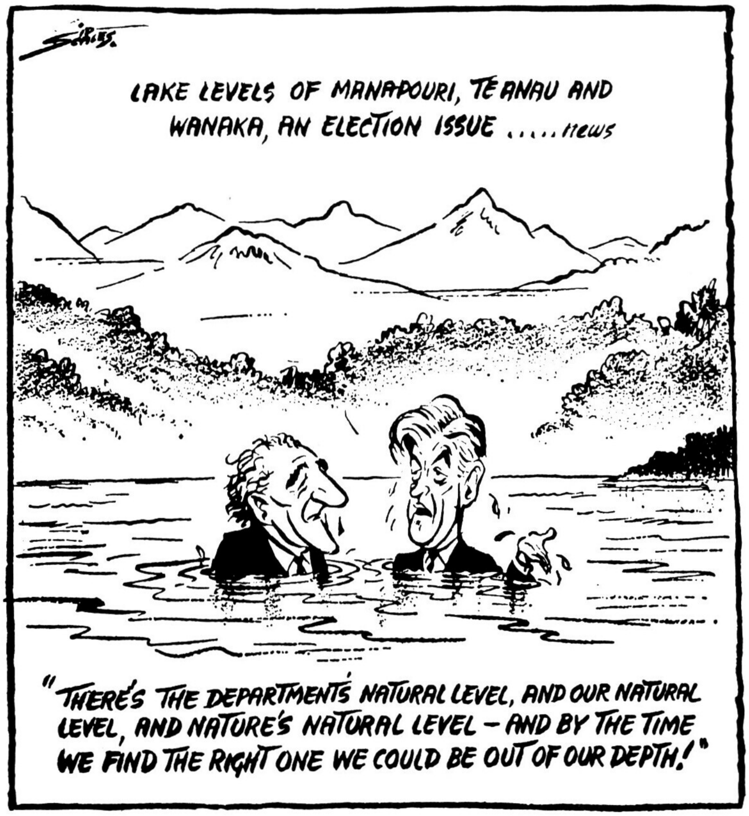
Cabinet agreed that the lake should not be raised, and a week later approved the terms of reference for the formation of the Guardians of

Lake Manapouri, a body of six members, and associated representatives from the National Park Board, the Southland Catchment Board, the Electricity Department and other government departments, and from the University of Canterbury. This represented a new philosophy of involving community and environmental groups in conservation issues at the offical level. Professor Alan Mark, an active Save Manapouri campaigner, was appointed chairman of the Guardians. They were to report to the new Minister for the Environment and were responsible for the protection of shorelines against damage caused by level changes.

The Guardians were determined to establish guidelines within which the lakes could be worked, and they doggedly monitored lake levels and corresponded endlessly with the Commission for the Environment, the Electricity Department, and the Ministry of Works and Development. The Electricity Department struggled (unsuccessfully) during the dry years of 1973 and 1974 to keep within the guidelines by using the lake for Comalco only when the situation was desperate. By March 1973 Lake Manapouri had been below the guideline level of 580 feet for 65 days.

With an election looming in 1975, the Guardians drew public attention to the lack of any legislation protecting lake levels. In November both major parties undertook to operate the lakes within their natural levels, and after National's election the Guardians pressed on with legislative proposals. Meanwhile the Te Anau control structure and Mararoa dam were completed in 1975 and 1976 respectively. In March 1977 the Guardians' draft legislation was sent to the new Minister for the Environment, Venn Young, but it had then to await negotiations with Comalco in December 1977. In that month the government accepted the guidelines as a guide but not as absolute rules fixing the levels, and a renegotiated agreement with Comalco meant that the government was no longer obliged to raise the lake.

Under the new agreement Comalco accepted that the Crown might supply them from any source, provided that the supply was continuous. This implicitly removed the need to raise the lake level. But the Guardians still wanted explicit protection. In September 1980 Venn Young, the Minister for the Environment, and Bill Birch, the Minister of Electricity, accepted the Guardians' guidelines as at least indicative if not absolute, and legislation was at last drawn up. The Manapouri-Te Anau Development Amendment Act was passed in 1981, and operating guidelines for levels were gazetted. Performance in relation to these guidelines is reported to Parliament annually. Their major goal achieved, the Guardians became involved mainly with monitoring lake levels.


LAKE LEVELS OF MANAPOURI, TE ANAU AND WANAKA, AN ELECTION ISSUE .....news
"THERE'S THE DEPARTMENT'S NATURAL LEVEL, AND OUR NATURAL LEVEL, AND NATURE'S NATURAL LEVEL – AND BY THE TIME WE FIND THE RIGHT ONE WE COULD BE OUT OF OUR DEPTH!"

Manapouri was an important issue during the election campaign of 1972. Jack Marshall, Prime Minister, and Les Gandar, Minister of Electricity, debate the point while the lake rises around them.

Sid Scales, *Otago Daily Times*, 6 November 1972

There were initially two potlines at Tiwai Point, but in 1982 a third was installed. The importance of the smelter to the New Zealand economy should be recognised. There can be little doubt that Southland, in particular, profited from the years of work on the Manapouri power scheme, and even more from having the smelter as a permanent employer. About 1,300 people are employed in the smelter, and many other jobs have been created indirectly.

CHAPTER ELEVEN

The Central North Island

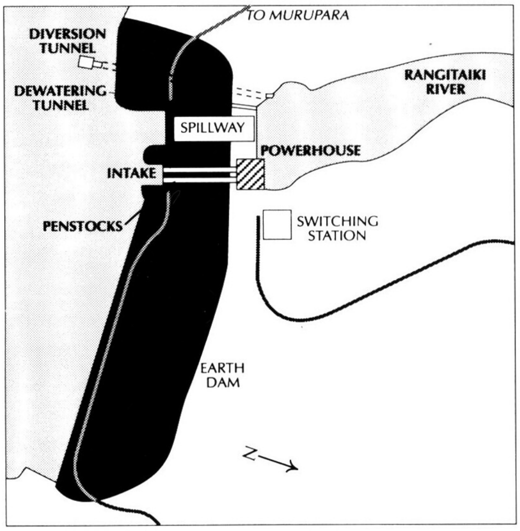
INTEREST TURNED to North Island rivers other than the Waikato in the early 1950s as people became aware that the high post-war growth in the consumption of electricity was likely to continue for the next decade. In order to provide the additional capacity required, there was investigation and exploitation of central North Island rivers such as the Tongariro and other water resources of the Volcanic Plateau, and the Rangitaiki River.

Matahina

The potential of the Rangitaiki River was investigated for four years in the late 1950s. A site at the mouth of the Rangitaiki Gorge was chosen for the Matahina dam.[1] The geological conditions were particularly difficult, and if this had been fully appreciated from the beginning the project might never have been started. The river had worn through the solid ignimbrite rock in its bed, exposing loose gravel and rock. In 1959 the Power Planning Committee recommended approval of Matahina and this was given by the government later that year. The first power was to be generated in April 1965, when there was expected to be a shortfall in capacity. Tenders were soon called for the diversion tunnel, and work began in 1960 on roading, construction of the village of Te Mahoe, excavation and the driving of the diversion tunnel, which was 25 feet in diameter, 800 feet through a rock abutment on the west side of the river. Further investigations had shown complicated faulting patterns and pumice beds under the rock at one of the abutments.

In 1961 the Power Planning Committee, reconstituted under Goosman, decided that Matahina was no longer urgent and could be delayed for two years because of the new priority given to the Cook Strait cable. The fact that plant designated for Maraetai II was reallocated to Matahina when the former was shelved created much extra design work, and construction slowed down. The diversion work had been let to a French firm; by early 1962 most of the tunnel had been driven and it was more than half lined with concrete. The

Matahina: Constructed 1960–67. Head 200 feet. This is the North Island's largest earth dam, at 5 million cubic yards, and was surpassed only by Benmore at the time. It is 282 feet high, 1,132 feet long and 1,200 feet wide at its base. Two steel penstocks, 16 feet 6 inches in diameter, lead water to two turbines which drive 36 MW generators. Total capacity is 72 MW.

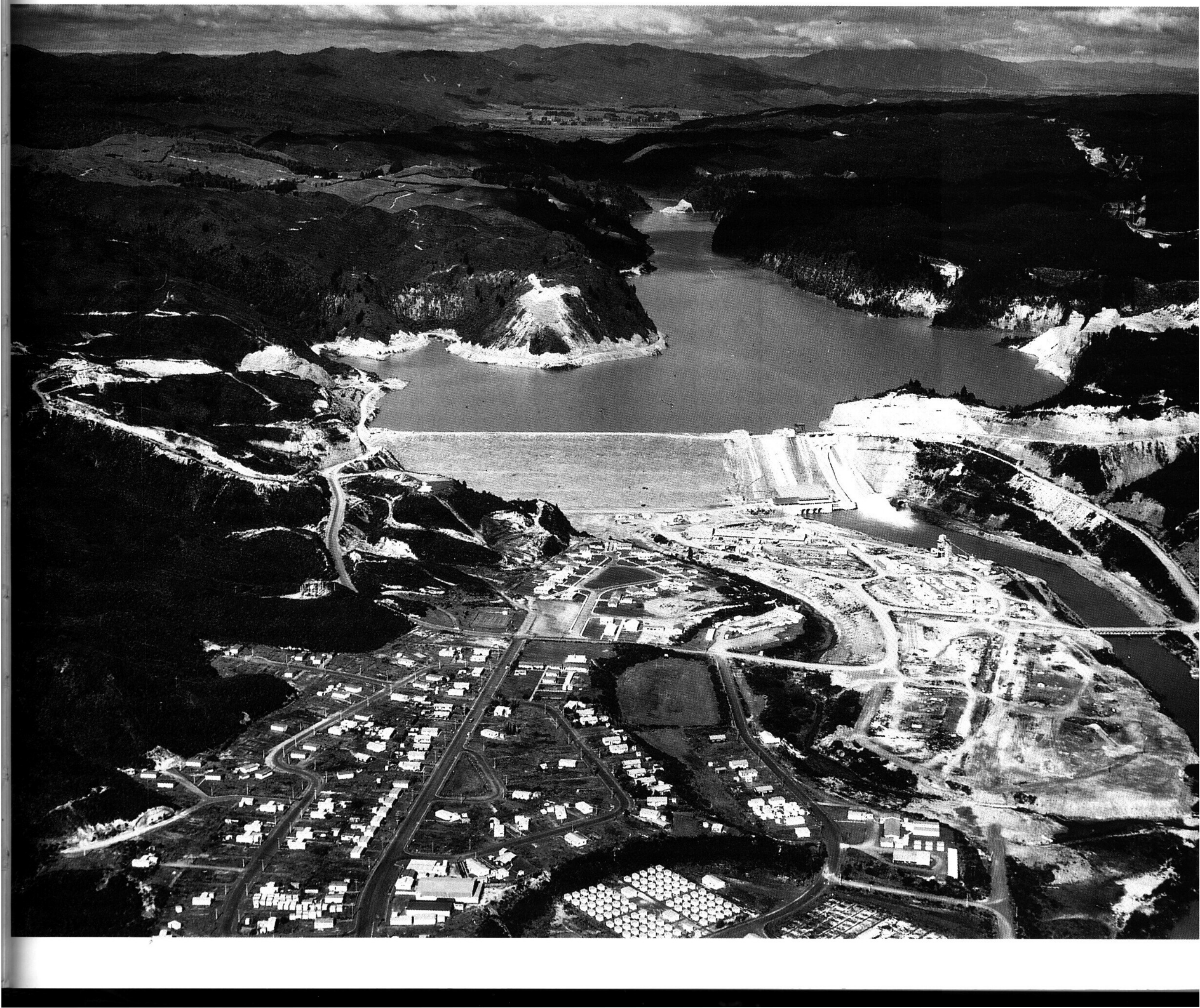


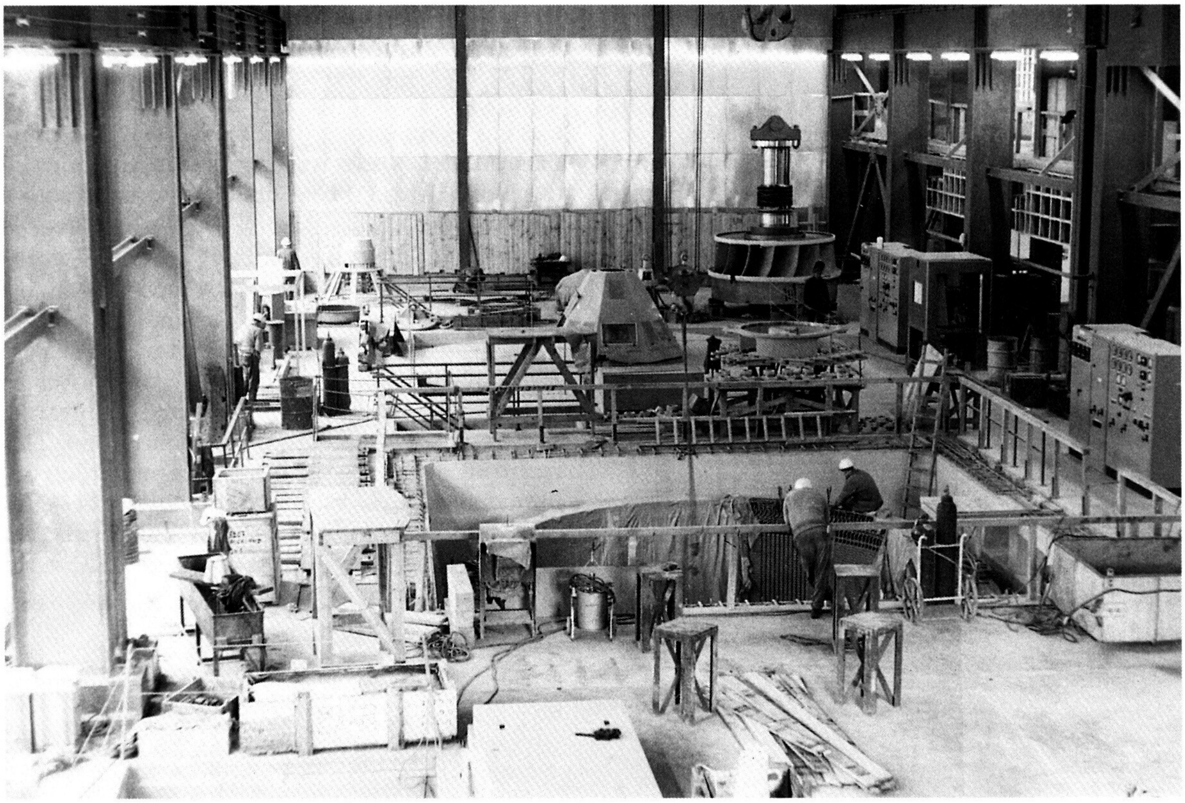
diversion was completed late that year after scouring necessitated strengthening of the tunnel outlet.

Construction now began to speed up, and the work-force doubled as men were released from elsewhere. Work began on the dam foundations, made more complex by the need to minimise seepage. A huge trench, up to 80 feet deep and 160 feet wide, was excavated to remove river debris, and an earthquake-resistant cut-off wall, twenty feet deep and made of special 'plastic' concrete, was built within it. Sixty drainage wells were drilled to 100 feet below foundation level and filled with gravel.

By 1963 the intake and spillway structures were almost complete and the powerhouse was making good progress. The spillway, at more than 100 feet wide, was larger than any other in the North Island, being designed to cope with a flow of 70,000 cusecs in the Rangitaiki River in extreme flood conditions. By 1964 the work-force had reached its peak of almost 700 as the dam foundations were finished and the powerhouse was made ready for the turbines. The core of the dam, comprising 600,000 cubic yards of impermeable compacted weathered greywacke clay, was put in place from September 1964. This was flanked by graded layers of ignimbrite rock forming its shoulders. The rock abutments had to be extensively grouted to prevent seepage. In 1965 excellent progress was made and nearly

The Matahina scheme, built at the mouth of the Rangitaiki Gorge, has the largest earth dam in the North Island, here seen in early 1967 just after its completion. Part of the public works camp remains at the bottom of the photograph.
Whites Aviation





Turbine installation at Matahina. A vertical Francis turbine runner stands in the corner at the back waiting to be installed, while two men work on the generator stator in the foreground.

three million cubic yards of material were placed. The powerhouse was almost complete, all concrete structures had been finished, and the generating plant was being installed.

When the lake was filled it extended some twelve miles up the river through narrow ravines. The first unit produced power at the end of 1966 and was commissioned on 25 January 1967. However, the lake had to be lowered temporarily in order to deal with leakage which had caused some subsidence by the right abutment. This delayed the opening of the station. The lake was then refilled and the second machine was commissioned in April. Full power was available by the winter of 1967 as planned.

The dam withstood the severe eastern Bay of Plenty earthquake of March 1987, although some repairs were necessary. These were undertaken in the first six months of 1988, and involved replacement of part of the core. The opportunity was also taken to repair the erosion damage of 1967.

The Tongariro development

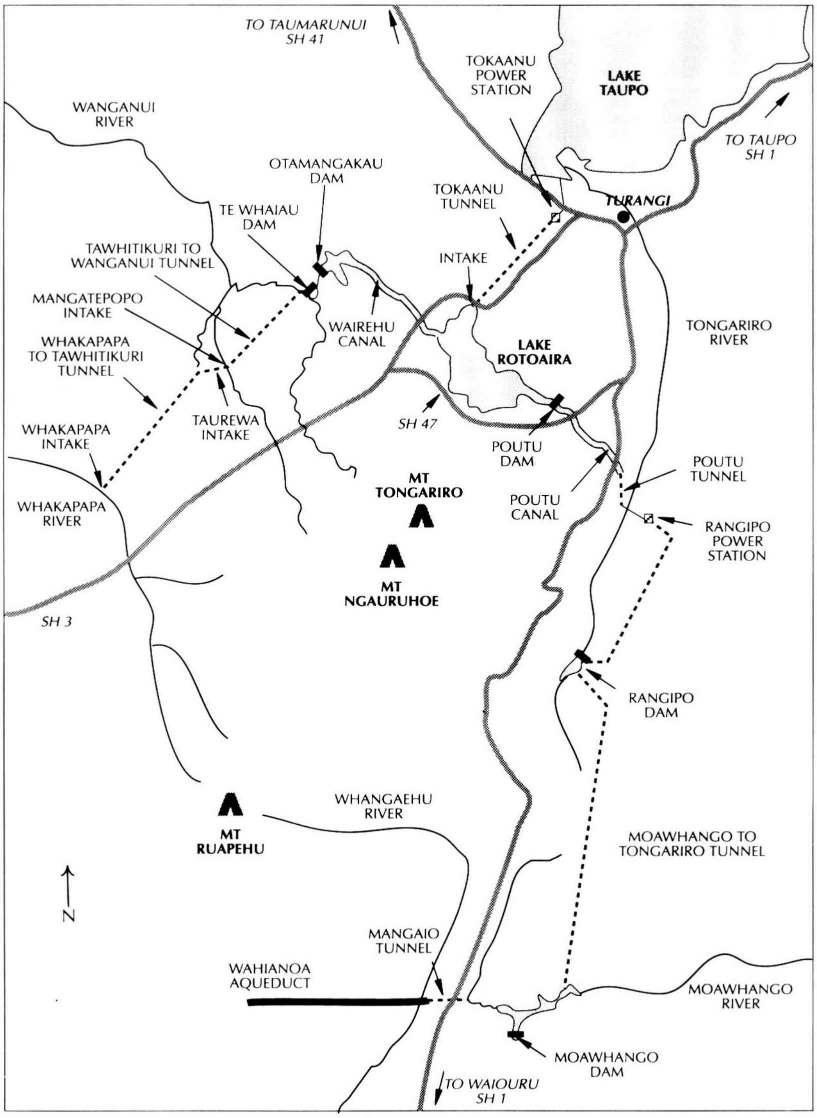
The Tongariro power development is a complex system of river and stream diversions, tunnels and canals, lakes and power stations in a catchment of more than 1,000 square miles.[2] The water gathered in the diversion on the eastern side of the volcanic mountains (the Eastern Diversion) generates power in the underground Rangipo power station before being led to join water from the diversion works on the western side of the mountains (the Western Diversion) to generate further power at Tokaanu. The diverted water assists with Lake Taupo's storage and increases the lake's outflow by more than 20 cumecs, thereby substantially increasing the energy generated by Waikato stations. The development as a whole provides 40 per cent of the North Island's hydro-electric energy.

The plateau and volcanic mountains south of Lake Taupo in the central North Island had not gone unnoticed as a possible source of electric power. The Public Works Department had done some surveying in 1924 when the Tongariro National Park Board was seeking water and an electricity supply for proposed hostel sites in the park. In 1941 an ingenious engineer at Waiouru Military Camp proposed harnessing the nearby

Moawhango River for power, and, although his plans were rejected, Kissel suggested that a record of its flow might be useful in the future. In 1945 the District Engineer at Taumarunui reported to Wellington on the Poutu Stream, the outlet for Lake Rotoaira. Nothing further happened until the summer of 1947, when, during investigations of low summer flows, an assistant engineer at the Taumarunui office became interested in the power potential of the area. Largely through investigations undertaken in his own time, he produced a report on the possible diversion of water from the Wanganui watershed. This was not favoured by Kissel, probably because of opposition from local people. However, Kissel was sufficiently interested to suggest a comprehensive study of a complete development, but no staff were available for this.

Information continued to be gathered. In 1948 a surveyor in the Mangakino office prepared a report on the 'Potentialities of the Upper Waikato Catchment'. He explored G. P. Anderson's suggestion that Lake Rotoaira, augmented by collecting some of the tributaries of the Wanganui River and the Poutu Stream, could be tapped by a tunnel under Mount Pihanga to Lake Taupo. He also discussed the Rangipo site and the problems that might arise if the acidic waters of the Whangaehu River flowed into the Tongariro.

By 1952 thinking had advanced considerably. There were proposals to take in the entire Volcanic Plateau catchment above 2,000 feet, the


TO TAUMARUNUI
SH 41
TOKAANU
POWER
STATION
LAKE
TAUPO
WANGANUI
RIVER
TO TAUPO
SH 1
OTAMANGAKAU
DAM
TOKAANU
TUNNEL
TURANGI
TE WHAIAU
DAM
TAWHITIKURI TO
WANGANUI TUNNEL
INTAKE
MANGATEPOPO
INTAKE
WAIREHU
CANAL
TONGARIRO
RIVER
WHAKAPAPA
TO TAWHITIKURI
TUNNEL
LAKE
ROTOAIRA
WHAKAPAPA
INTAKE
TAUREWA
INTAKE
SH 47
POUTU
DAM
POUTU
TUNNEL
MT
TONGARIRO
WHAKAPAPA
RIVER
POUTU
CANAL
RANGIPO
POWER
STATION
MT
NGAURUHOE
SH 3
RANGIPO
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RUAPEHU
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MOAWHANGO TO
TONGARIRO TUNNEL
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MANGAIO
TUNNEL
WAHIANOA
AQUEDUCT
MOAWHANGO
RIVER
MOAWHANGO
DAM
TO WAIOURU
SH 1

The Tongariro Development

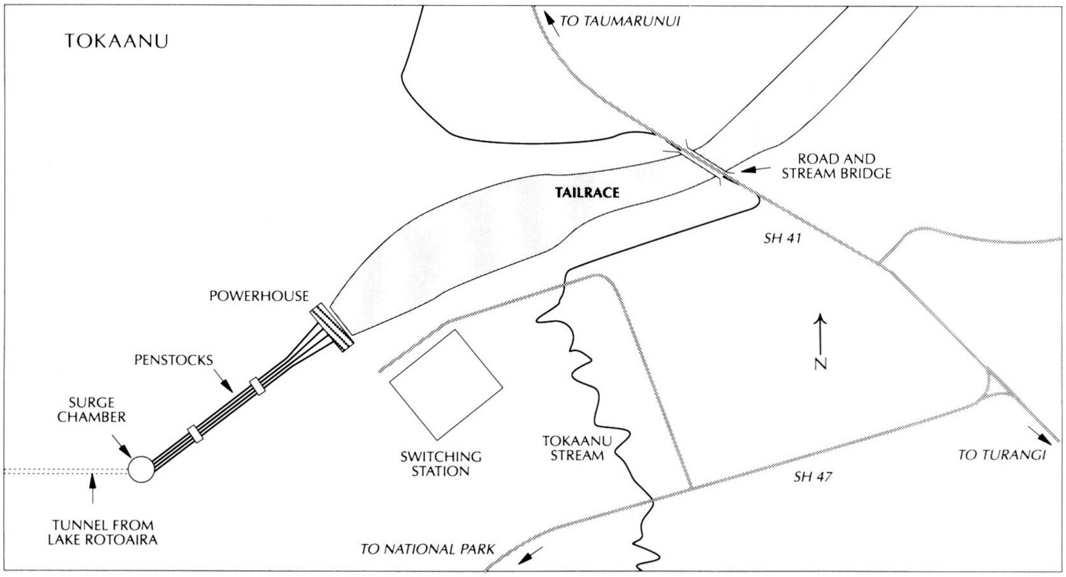
A four-stage development constructed over the period 1964–83.

Stage 1 — Western Diversion: Constructed 1964–71. Water was diverted from five tributaries and the headwaters of the Wanganui River. Two tunnels, 6½ and 3½ miles long, linked the Whakapapa and Wanganui Rivers, and there was a Mangatepopo branch tunnel 400 feet long. Three canals — Te Whaiau, 1,355 feet long; Otamangakau, 4,000 feet long; and Wairehu, 4¼ miles long — lead into the Wairehu Stream and Lake Rotoaira. The earth-fill Te Whaiau dam is 45 feet high and 180 feet long, and the earth-fill Otamangakau dam is 66 feet high and 853 feet long. A total of 2.7 million cubic yards of material was excavated for this stage.

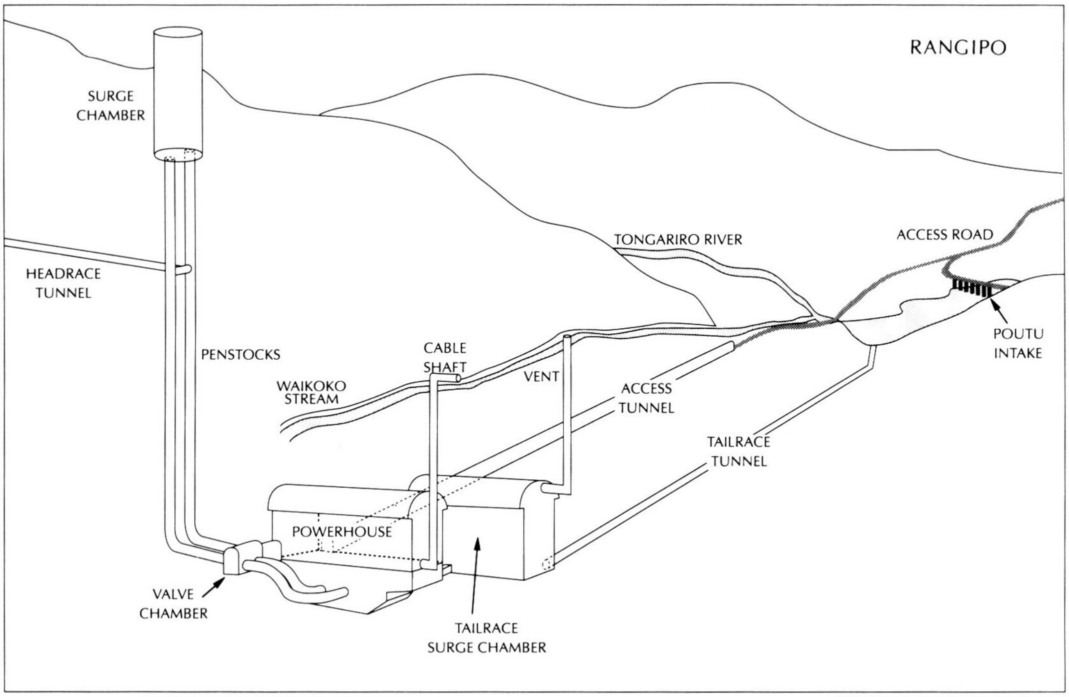
Stage 2 — Tokaanu: Constructed 1966–73. Water is led from the Tongariro River through an intake in the riverbed along the 1¾-mile-long Poutu tunnel and the 3½-mile-long concrete-lined Poutu canal into Lake Rotoaira. A concrete-lined tunnel, 3¾ miles long and 21 feet in diameter, runs from Lake Rotoaira to a surge chamber, which leads to four 1,200-foot-long steel penstocks dropping down to the powerhouse at Tokaanu. The Poutu dam is a concrete gravity dam, 43 feet high and 492 feet long, controlling the outflow from Lake Rotoaira. The Tokaanu powerhouse has a head of 208 metres. Four turbines drive 50 MW generators, giving a total capacity of 200 MW. A tailrace canal leads the water 2½ miles into Lake Taupo. The total excavation for this stage, excluding tunnels, was 5.3 million cubic yards.

Stage 3 — Eastern Diversion: Constructed 1969–79. The Wahianoa aqueduct, 5½ miles of pipeline, leads water into the 4,200-foot-long Mangaio tunnel which discharges into the Mangaio Stream and thence to the Moawhango reservoir. The Moawhango concrete gravity-arch dam is 325 metres long and 68 metres high. The 12½-mile-long Moawhango-Tongariro tunnel takes water from the reservoir to the Tongariro River and the Rangipo dam.

Stage 4 — Rangipo: Constructed 1974–83. The Waihohonu Stream is diverted into the Rangipo dam via a concrete gravity dam, 15 metres high and 32 metres long, and a 1-kilometre tunnel. The Rangipo dam is a concrete gravity structure on the Tongariro River, 23 metres high and 150 metres long, incorporating an intake and a 60-metre-deep shaft for the Rangipo headrace tunnel. The concrete-lined headrace tunnel, 8 kilometres long and 4.5 metres in diameter, leads water to a surge chamber just above the underground Rangipo powerhouse, which has a head of 240 metres.



One vertical penstock, 4.5 metres in diameter and 180 metres long, bifurcates into two horizontal 2.4-metre-diameter penstocks 150 metres long. These lead the water to the powerhouse, which is 80 metres underground with access via a 680-metre-long tunnel with a one-in-ten gradient. The powerhouse cavern is 55 metres long, 18 metres wide and 36 metres high, with its floor constructed midway up the walls. Two turbines drive 60 MW generators for a total capacity of 120 MW. The switchgear is installed in the machine hall, and the powerhouse is remote-controlled from Tokaanu. A large tailrace surge chamber immediately downstream from the powerhouse feeds into a 3-kilometre tailrace tunnel running back to the Tongariro River.



lowest level from which a diversion into Lake Taupo could be made. In 1955 consultations began between the Ministry of Works and other departments. The most important issues were tourist fishing interests and the land and fishing rights of the local Maori landowners, particularly Ngati Tuwharetoa. The Dominion Laboratory was consulted on the chemical properties of the Whangaehu River, which drained the Mount Ruapehu crater lake, and the effect of introducing its water into the Tongariro River.

Informal discussions convinced the Ministry of Works that Ngati Tuwharetoa would be prepared to come to terms. The first meeting with the Tuwharetoa Trust Board and Maori landowners took place in October 1955, when some 60 kaumatua (elders) gathered to meet representatives of the Department of Maori Affairs and the Ministry of Works. An official described the proposals and stressed the necessity for further investigation, the determination to safeguard fishing interests and the importance of the co-operation of the Maori people in all aspects of the scheme. The trust board expressed sympathy with the proposals but felt that with no concrete plans available the matter should be deferred.

In October 1955 Cabinet authorised the engagement of Sir Alexander Gibb and Partners for preliminary investigations. The firm had international experience in the design of hydro-electric projects and was known for its work on Atiamuri; it was an obvious choice once the principle of engaging consultants had been accepted. As the potential significance of the investigations became public, the first protests occurred. In December 1955 the secretary of the Waimarino Acclimatisation Society wrote to the Commissioner of Works protesting against any 'proposal to divert the flow of the Wanganui River into Lake Rotoaira for power purposes'. Early in 1956 a senior Ministry of Works engineer made a tour of inspection and reported in some detail on the various dam and diversion sites. His conclusion was that the proposal was economically viable.

The consultants' preliminary report of September 1957 set out a number of options and assessed the power potential. Attractive features of the proposal were the feasibility of proceeding in progressive steps and the low demand on overseas funds.

Gibb and Partners then carried out more detailed investigations. Their 1962 interim report confirmed much of the original proposal and recommended that the Western Diversion commence first as Stage 1. This scheme would intercept various tributaries and the headwaters of the Wanganui River and lead the water via two tunnels to two lakes on the Otamangakau and Wanganui Rivers. The water was then to be led to Lake Rotoaira (and thence into Lake Taupo through a tunnel as part of Stage 2). Lake Rotoaira was to be kept within the range of its natural levels in order to interfere as little as possible with the fishing rights of the Maori owners. The diversion would allow the generation of an extra 420 GWh annually from existing Waikato stations. Stage 2 involved a tunnel from Lake Rotoaira to Tokaanu on the shore of Lake Taupo, where a power station would take advantage of the substantial head between the two lakes and generate 629 GWh from three of its four planned units by using water provided by the Western Diversion. Initially there was to be another power station before Lake Rotoaira, but this proposal was deleted from the 1963 final report.

The Eastern Diversion (and a fourth unit for the Tokaanu station) comprised Stage 3. On the eastern side of the mountains the Moawhango River could be diverted below its confluence with the Mangaio Stream, turned from its natural southward course into the Rangitikei River and brought across country to the Tongariro River. By damming the Moawhango a reservoir could be formed into which the tributaries of the Whangaehu River and many other southern Ruapehu streams could be diverted by the Wahianoa aqueduct. (The high sulphuric acid content of the main Whangaehu River led to its exclusion from the scheme.) Some of the water in the Tongariro would also be led to Lake Rotoaira. This would increase the Tokaanu power station's energy potential by 194 GWh annually and would allow the installation of a fourth machine. The additional flow in the Tongariro would also yield 285 GWh annually in the existing Waikato stations.

As Stages 4 and 5, two more power stations were proposed for the Tongariro River, a lower one at Beggs Pool, above which natural barriers prevented fish from travelling upriver, and a higher one at Rangipo, which together would produce 551 GWh from both Tongariro River and diverted water. The lower station was subsequently dropped. The 1963 Power Planning Report proposed that the Western Diversion should be completed by April 1970, the Tokaanu power station with three machines by April 1971, and the Eastern Diversion and a fourth machine at Tokaanu by April 1972. The Rangipo project was to be confirmed later.

The public announcement of these plans gave rise to concern. The local newspapers carried anxious reports, and the Wanganui Harbour Board and the Wanganui River Scenic Board sent telegrams to the Minister. Election meetings in Taupo in 1963 were enlivened by questions on the possible impacts of the scheme. The Ministers of Marine and Internal Affairs issued a press statement on the first three stages of the development, which guaranteed continued adequate flow in the Tongariro River and suggested that fishing resources would in most cases be improved.

The Waikato Valley Authority, responsible for water management issues, was particularly concerned about control of the Waikato River, given the proposed increased flow and raised water levels. There had been discussions with the authority since 1958. In July 1964 the new Minister of Works, P. B. (Percy) Allen, assured it that any problems caused by the diversion would be made good at no cost to the authority. After a special meeting in August with Tom Shand, the Minister of Electricity, and Mackenzie, his General Manager, the authority voted to support the scheme.

The Taumarunui Borough Council was worried that reduced flow in the Wanganui River would affect its own small generating station at Piriaka, as well as the borough's water supply and sewerage system. In 1959 the council had written without success to the Electricty Department asking for details of the scheme. Approval in principle for the development in 1964 brought an immediate protest from the council and led to meetings with the department and the Ministry of Works. Negotiations centred on the flow required for the Piriaka power station. Eventually the council accepted the Electricity Department's offer of compensation for flows lower than required.

An awareness of the possible impact on trout fisheries had been a factor in planning from the start. In 1955 there had been an inter-departmental committee on the subject. The main concerns were to maintain sufficient water in the Tongariro River for spawning, avoid rapid changes of flow, preserve feeding grounds in Lakes Rotoaira and Taupo, improve access to fishing pools, and the removal of sediment from the river. The Marine Department, in conjunction with the Wildlife Branch of the Department of Internal Affairs, established the desired minimum flow of the Tongariro at Turangi during the spawning season, as 1,000 cusecs. The Gibb report of 1962 included this constraint in its calculations, commenting that this would restrict the water available at Tokaanu. A report commissioned from the Marine Department suggested that there would be no major problems for the fisheries provided that the Tongariro River and Lake Taupo were protected, but acclimatisation societies and the Nature Conservation Council felt that the upper Wanganui-Whakapapa area had been ignored.

After the election in late 1963, Mackenzie asked Cabinet for formal approval of the first three stages. The rising demand for electricity and the availability of the Mangakino work-force were important factors. In March 1964 Shand announced the approval in principle of the first three stages, subject to the interests of adversely affected parties being protected, and the engagement of Gibb and Partners to undertake the detailed designs. Thus, as work on the Waikato came to an end, work on the next major North Island hydro-electric development began. In recognition of this, Project Head Office moved from Mangakino to Turangi in November 1965.

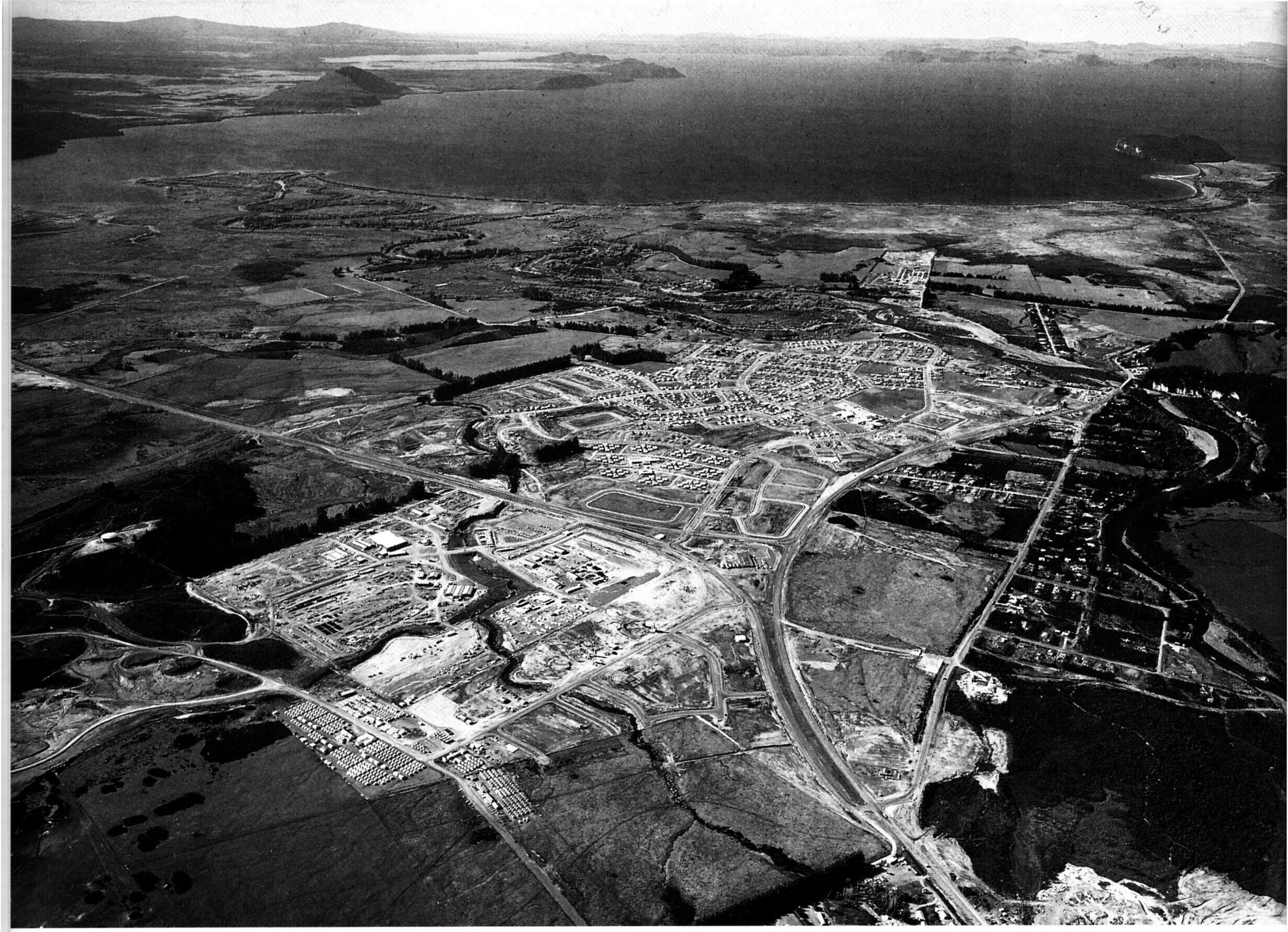
Turangi was a small, largely Maori settlement of about 500 people. The town was designated as the construction base and a population of 8,000 was planned for. Building a substantial town around an existing settlement was a new role for the Ministry of Works, and a commitment was made to a permanent enlarged town with housing of appropriate standards, carefully planned residential and industrial areas, a shopping complex, schools and a library.

Meetings with Maori landowners, which began in April 1964, dealt particularly with the purchase of land and planning for the town. The issues involved included land within the township occupied by the Hirangi Pa, which belonged to the Ngati Turangi subtribe, and urupa (burial grounds) in the proposed industrial area of the town and near the tailrace of the planned Tokaanu station.

The Turangi Township Act, passed in December 1964, set out the form of the town's administration by the Turangi Liaison Committee and the acquisition of land. It was proposed that 900 acres should be purchased and a further 200 acres leased from Ngati Tuwharetoa. A temporary camp for 200 men was set up at Turangi at once. By 1967, 1,300 residential and commercial sites were being developed, some 600 houses were occupied and a maternity hospital had been built. A new Tongariro High School, with 530 pupils, had replaced the old Tokaanu District High School, and there were two primary schools. By March 1969 Turangi's population had reached 5,000 and by later in the year more than 30 shops and businesses had opened. The town's population rose to about 6,000 in 1971 and remained at about 5,500 over the following decade before declining to around 4,000 by 1986.

The huge Tongariro development area contained within it much evidence of the history of the local Maori people. In 1965 the Project Engineer invited the Historic Places Trust to survey sites in the area. A large number of pa sites were recorded, as was Te Kooti's redoubt at Te Porere near Lake Rotoaira. The urupa in the area of the Tokaanu power station tailrace was located, and remains were reinterred at Tokaanu along with those from another urupa on the Te Ponanga Saddle Road.

While work had in fact already begun during 1964, the Ministry of Works still awaited official approval to start. The Waikato work-force was meanwhile scattered from Aratiatia to Waipapa doing maintenance work. Cabinet, for its part, was mindful of public opinion and sought guidance from the recently formed Nature Conservation Council. The council eventually approved the proposals by a majority, but with the proviso that the recreational values of the Tongariro River must be preserved. The government also met the Tuwharetoa Trust Board, the Waikato Valley Authority, the Taupo County Council and many other concerned groups, and issued press statements. An acrimonious battle developed between Shand and Peter McIntyre, a war artist and popular painter of New Zealand landscapes. McIntyre had been elected President of 'The



Turangi, on the southern shore of Lake Taupo, was the centre for the Tongariro power development. In this December 1966 photograph the old part of the town lies close to the Tongariro River and to the right of the main highway, which curves around towards the eastern side of the lake. The large new section of the town lies to the left of the main highway, with permanent housing beyond the highway junction and construction facilities and a public works camp in the foreground.
Whites Aviation

Hands off Tongariro and Surroundings Movement', which enraged Shand by referring to power planners as 'rampaging philistines'. The press both reported the controversy, complete with cartoons, and, with unconscious irony, publicised the rising demand for power and the particularly heavy load that winter.

In September 1964 Cabinet approved an immediate start on the first three stages. As Percy Allen, the Minister of Works, observed, the development 'centred on one of New Zealand's most notable scenic and sporting areas'. He promised to do everything possible to minimise the disturbance and to preserve aesthetic values.[3] Apart from the work to be done by the Ministry of Works, there were a number of very substantial contracts to be let, for the Whakapapa-Wanganui, Tokaanu and Moawhango tunnels, for the Moawhango dam, and for the Wahianoa aqueduct and the Mangaio tunnel.

In 1965 tenders were let for the supply of turbines and generators for the Tokaanu power station and for three tunnelling contracts. An Italian combine, Codelfa-Cogefar, had tendered competitively for the long Whakapapa-Wanganui and Moawhango tunnels and wished to use a large number of Italian tunnellers. Cabinet refused to let work go ahead until an agreement was reached with the Federation of Labour. The federation would have preferred an extended time schedule for the Manapouri, Tongariro and the large Kaimai railway tunnel projects, which were being undertaken simultaneously, so as to prolong the availability of work. With the decision to start them all having been taken, it held out for the best possible pay and conditions.

Codelfa-Cogefar argued that Italian labour was cheaper because of low labour turnover rather than lower wages. When tenders were considered in February 1966 a speedy solution seemed possible. Shand met Tom Skinner, the President of the Federation of Labour, and it was decided that the negotiation of agreements should be completed before the government signed the contracts. The federation wanted New Zealand labour to be advertised for first, limits on the number of Italian workers, and the same conditions and standards of accommodation for them as for local workers, as well as 'satisfactory' rates of pay. The government wished to prevent rates rising at different hydro-electric sites through a 'leapfrog' effect. It was concerned by a clause in the Tongariro contract providing for recompense by the government for any wage rates higher than those at Manapouri. The Federation of Labour regarded the government's intervention as illegitimate interference in their negotiations with an employer.

Meanwhile in September 1966 the Ministry of Works began the task of damming the Wanganui at Taurewa, the first part of the Western Diversion, and made a start on the Poutu dam. Work also began on excavations for the Te Whaiau and Otamangakau dams and on the penstock slope, powerhouse and tailrace canal at Tokaanu. These workers were anxious for a settlement, since slower progress would mean cuts in working hours, but the government wanted to reduce expenditure and proposed to lengthen the project by one year. Tunnel contracts would not now be let until the next financial year. This removed the urgency for a settlement of the dispute.

The Federation of Labour resumed discussions with Codelfa-Cogefar at the end of October, some six months after the break in negotiations. In November it was agreed that Codelfa-Cogefar would receive an additional cost allowance and one-third of any subsequent escalation, exclusive of wages. The company could recruit 185 men initially, and later up to two-thirds of its workforce could be Italians. There was some increase on Manapouri pay rates, but the comparison was not straightforward when allowances were included. The contract was finally let in March 1967.

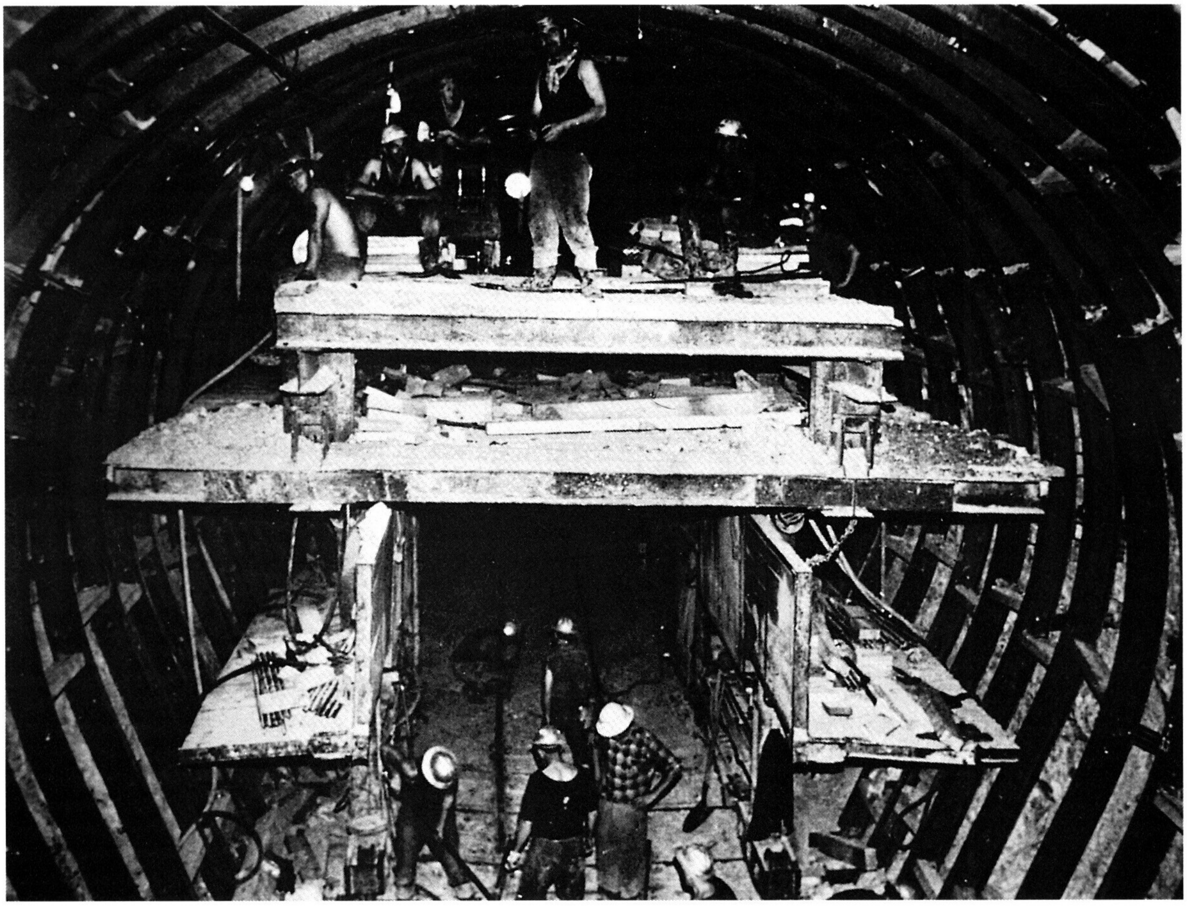
By midyear the Italian consortium had begun in earnest on the two Whakapapa–Wanganui tunnels. The tunnellers, most of whom were very experienced, were brought out in small groups for easier assimilation. The first New Zealand mass to their patron saint, Santa Barbara, was celebrated underground in December, and followed by a dinner. The tunnellers worked six days of eleven-hour shifts each week and sent back on average three-quarters of their wages to Italy. By early 1968 a mile of tunnel had been driven.

The final phase of the development was reconsidered in 1967. The Commissioner of Works proposed that Stages 4 and 5 should be combined into one scheme, thereby saving the gorge in the Tongariro River known as the 'Pillars of Hercules' and avoiding considerable public opposition. This would mean only one power station of 100 MW at Rangipo. He also favoured a less costly low dam and single reservoir at Moawhango. Another dam and pumping station that had been proposed could be eliminated. Indeed, the unprecedented reduced demand for power in 1968 gave rise to fears that the final stage might be scrapped altogether. This did not happen, but the less complex Ministry of Works proposals were accepted.

In December 1968 the contract for the Moawhango–Tongariro tunnel was finally let to Codelfa-Cogefar. Discord between the New Zealand Workers' Union and other unions on site had surfaced once again; it took a year for agreement to be reached with the Federation of Labour. The Ministry of Works decided to use its own men to drive the Poutu tunnel, which would link the Tongariro River with the Poutu canal.

With so much of the work underground, overall progress was largely dependent on the speed of tunnel construction. Test bores gave no more than a general picture and did not show up many difficulties that were to appear. Codelfa-Cogefar sought compensation after there had been a number of cave-ins in the Whakapapa–Wanganui tunnel when less than four miles had been driven. In May 1968 a fall of 2,000 cubic yards had buried much equipment. Two months later a further large slip made it necessary to realign the tunnel to bypass the troublesome area. This slowed progress considerably.

In 1969 Codelfa-Cogefar imported from the United States a new oscillating tunnel-boring machine which moved forward automatically while boring and was kept on course by a laser beam. The tunnellers worked from behind a protective bulkhead. On the whole this performed well, although it had to be modified when it came



Much of the work on the Tongariro development involved tunnelling. Here the 'jumbo' is shown in the Tokaanu tunnel. Tunnelling here proved difficult and unpredictable work, with large flows of water and hot and swelling ground caused by geothermal activity. The tunnel required substantial bracing, as shown here.

New Zealand's Latest Power Story — Tongariro Power Development, Ministry of Works and Development, 1974

up against sandstone later in the year. By early 1970 about seven and a half miles had been driven; a year later there was still half a mile to go.

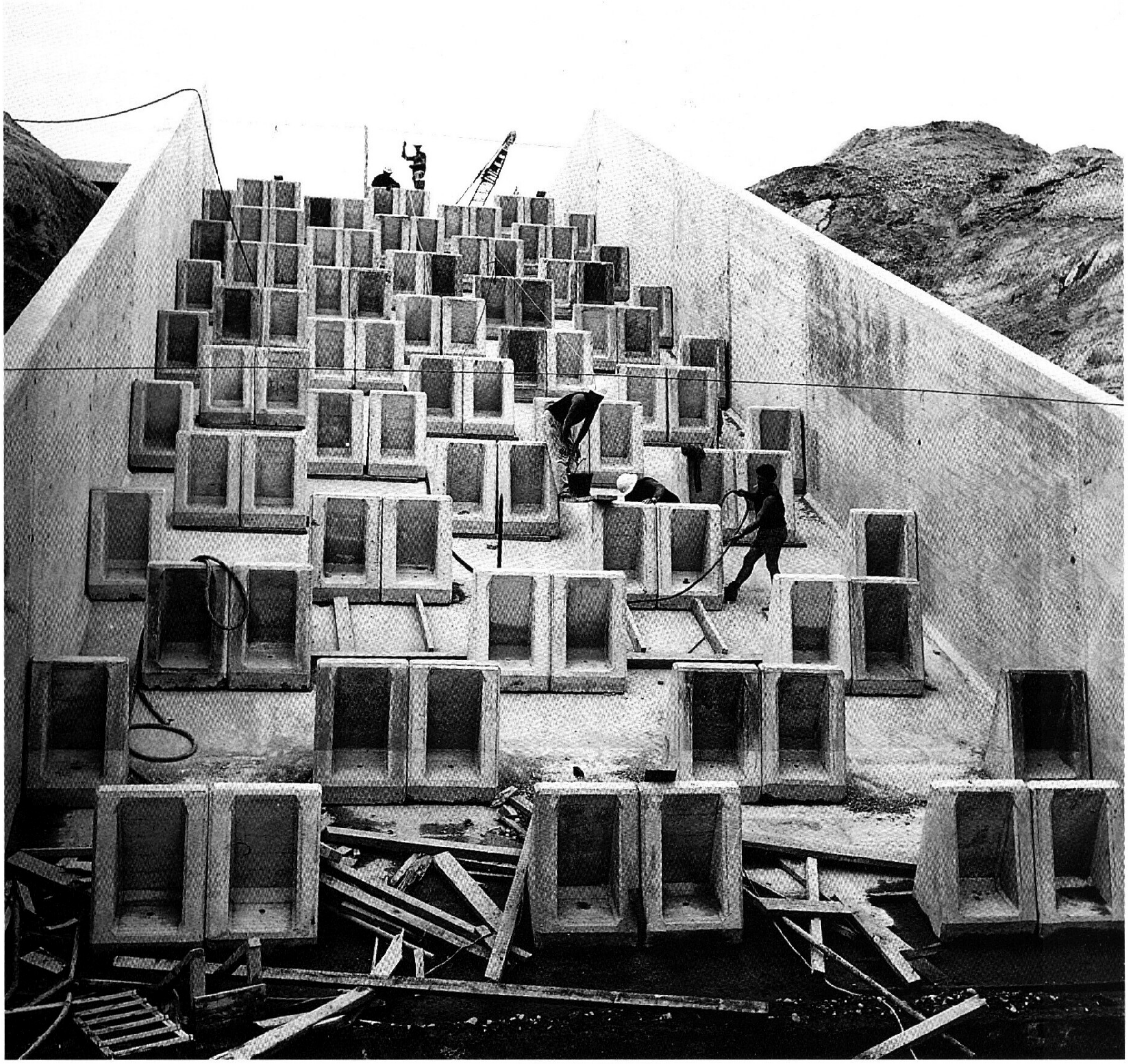
Downer and Associates, which had the contract for the Tokaanu tunnel (let in December 1967), at first fared better. In January 1969, after a year's work, they had tunnelled 3,400 feet into the hill and were on schedule. They had also excavated the powerhouse foundations, and the building was taking shape. The penstock slope had been completed and the tailrace begun. However, in April tunnellers were warned by an increased water flow in time to escape a fall of 1,000 cubic yards of rock. Thereafter progress was disrupted by increasingly difficult conditions, with large inflows of water and at times unworkable hot and swelling ground caused by thermal activity. By early 1970 only a mile had been driven because of these conditions, and a year later, after the situation had improved, two miles.

By early 1968 the Poutu Stream had been diverted to allow work on dam construction, and within a year the Ministry of Works had started on the Poutu tunnel. Good progress was made in 1970 on the other Stage 2 works, including the Poutu intake and canal, and the powerhouse and tailrace at Tokaanu. Some difficulty was caused by geothermal activity in the tailrace area.

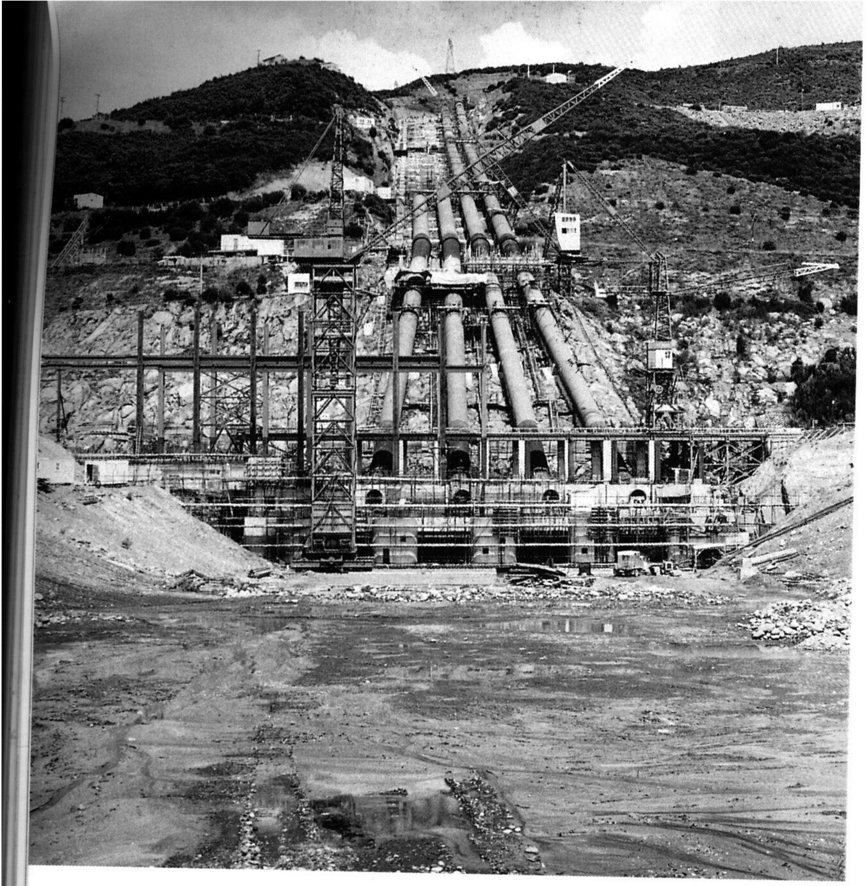
The first 'hole-through' was in early 1971 for the Whakapapa–Tawhitikuri section of the Whakapapa–Wanganui tunnel. By December the other section of tunnel had also been driven. The completion of the Te Whaiau and Otamangakau dams and the Wairehu canal was more immediately significant for electricity generation and a milestone in the project. Water was directed into the two new lakes in February 1971, and the Wairehu canal gates were opened to allow water to flow into Lake Rotoaira. Six months later the canal was carrying its full capacity. Until the completion of Stage 2 the additional water flowed down the Poutu Stream and into the Tongariro to augment the flow in the Waikato River. The Poutu tunnel was holed-through with an unblemished safety record in February 1972, three months ahead of schedule. The Poutu intake and canal were finished at the same time.

The drought in early 1973 created some urgency. Two of Tokaanu's four machines were installed and ready to operate, but the Tokaanu tunnel was not completed until the middle of the year. These units were commissioned in July 1973, the third in September and the fourth in March 1974. In December 1973 Tongariro water was diverted into Lake Rotoaira, and the Western Diversion and Tokaanu stages were complete. The station's capacity can be varied up to a maximum of 200 MW. It is used to minimise the use of expensive thermal plant and to meet rapidly changing demands for power.

Much time and energy had been put into minimising the impact on the trout fishery. The flows of the Tongariro River and the Poutu and Whakapapa Streams are carefully managed to assist in preserving the fishery. Fish screens at the downstream ends of waterways such as the Tokaanu tailrace and the Poutu canal prevented fish entering waters with no access to spawning grounds. The Poutu canal screens were soon



A water drop-chute at the beginning of the Wairehu canal. The triangular concrete blocks break up and slow down the water as it descends the chute.

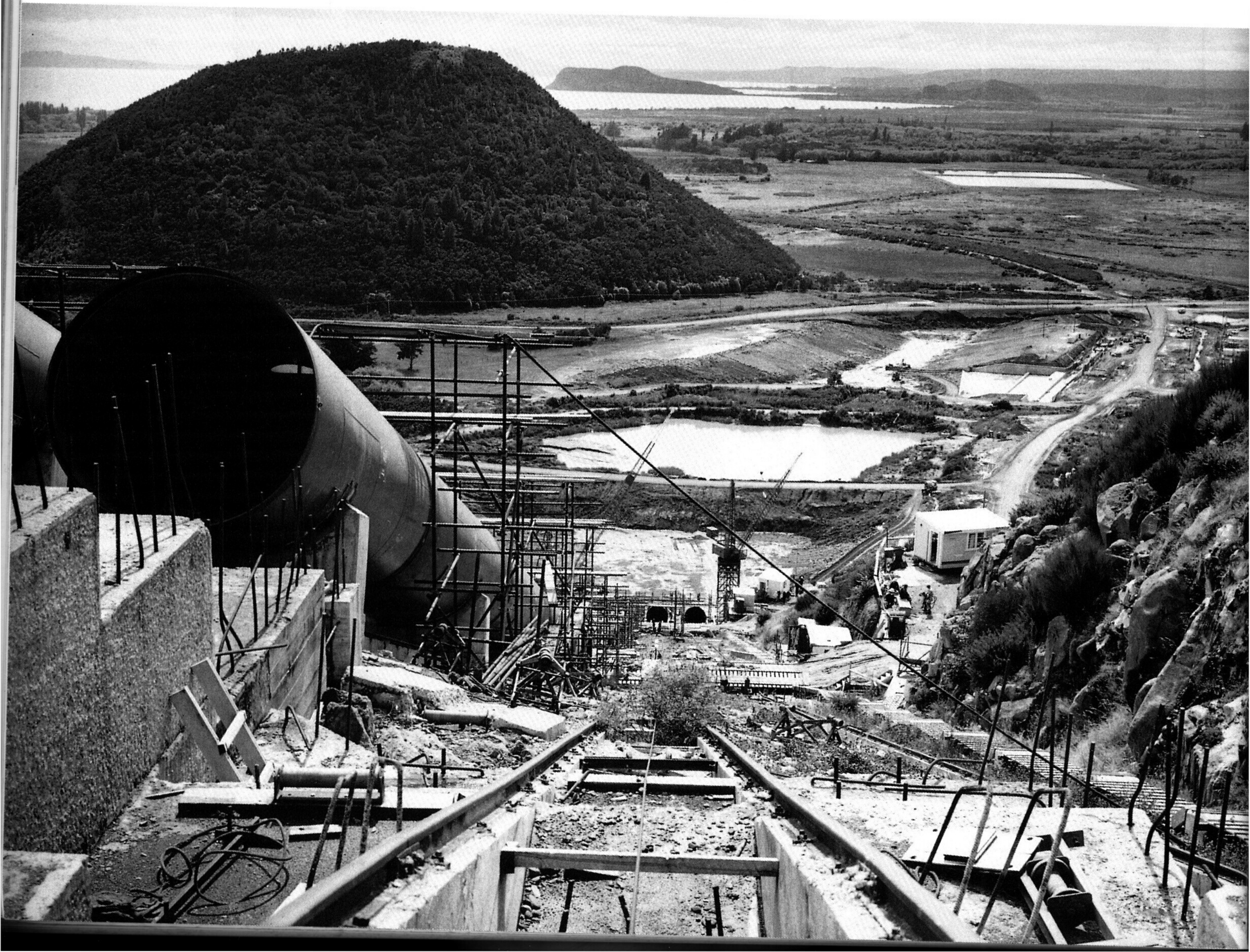


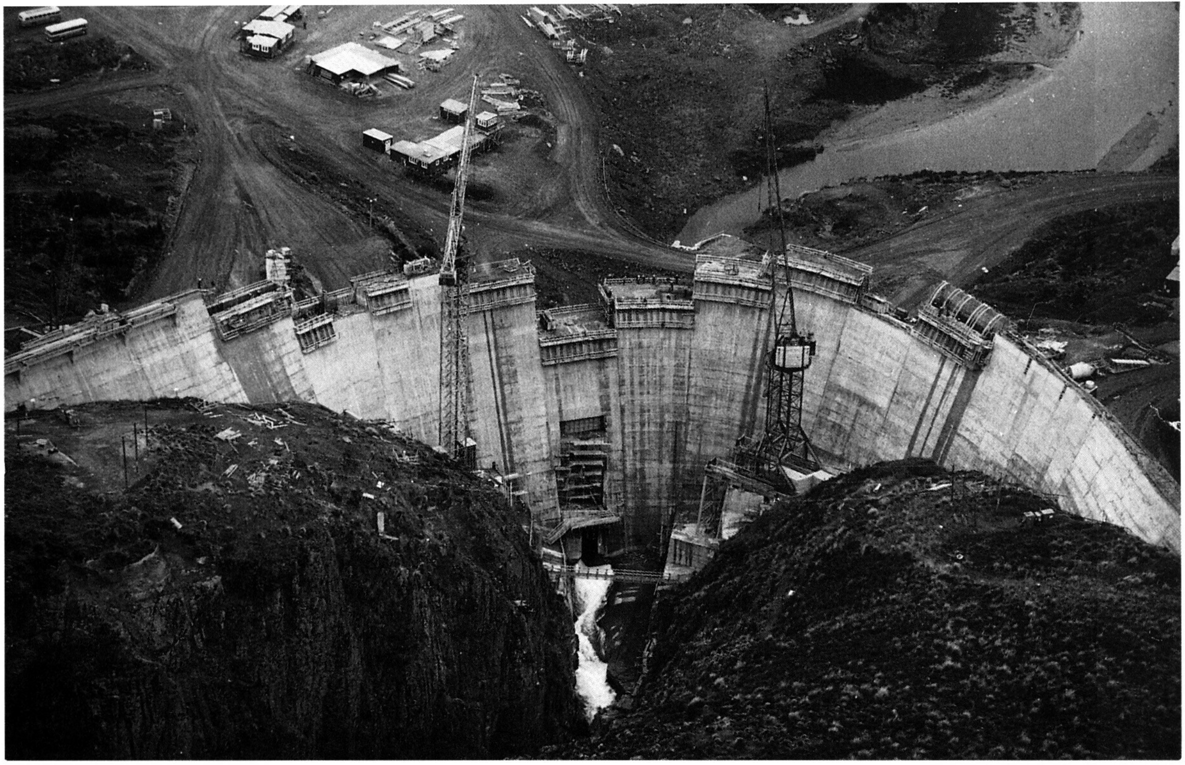
removed because of the risk of blockage and the trout population maintained by stocking from the hatchery instead. The tailrace screens were also removed after a few years when it was discovered that very few trout were going up the tailrace to spawn. The Tokaanu Stream is carried over the tailrace on the lower deck of the traffic bridge on State Highway 41 to preserve its unique spawning characteristics. Rotating drum screens were installed at Wairehu to prevent eels and lamprey from the Wanganui River getting into Lake Rotoaira and thence into Lake Taupo.

Work on the Eastern Diversion stage was by

Left: A view of the partially finished Tokaanu powerhouse from the tailrace.

Below: Looking past the incomplete Tokaanu penstocks to the powerhouse and beyond to the very large tailrace which curves around the peak of Maunganamu to join Lake Taupo. The coffer dams in the tailrace area allowed the important trout-spawning Tokaanu Stream to cross the excavation works.

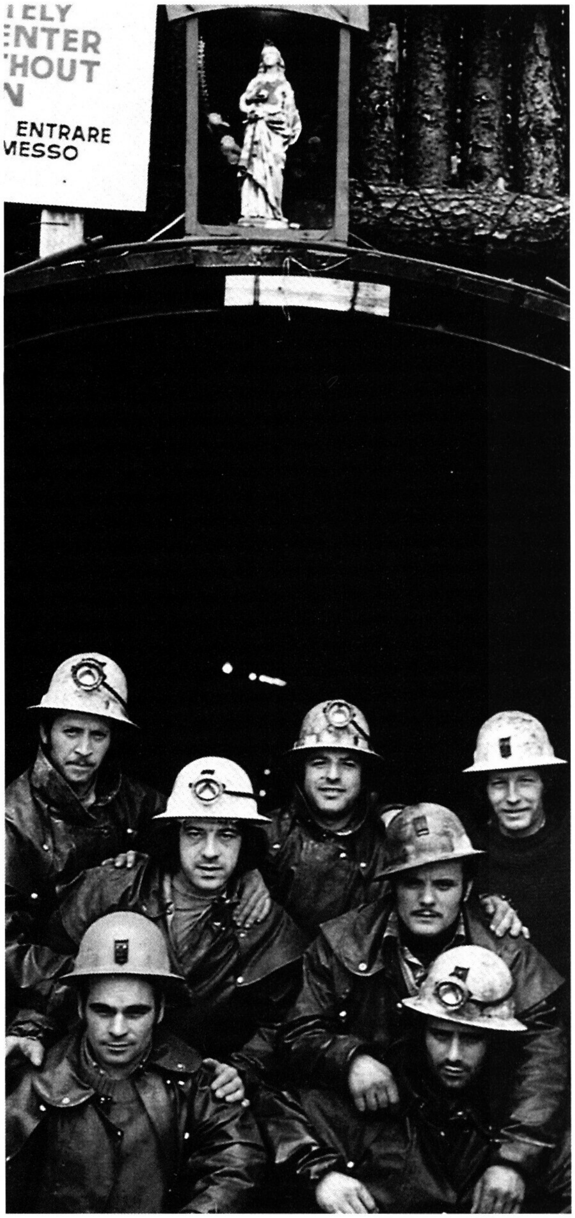




Above: The concrete gravity-arch Moawhango dam at the entrance to the Moawhango Gorge is shown under construction in February 1975.

now well advanced. Codelfa-Cogefar started the long Moawhango tunnel in April 1969 and found it to be a nightmare. By early 1971 only three miles had been driven, and a year later five and a half miles. By early 1972 concreting of the Moawhango dam had begun, and the Wahianoa aqueduct and the Mangaio tunnel had also been started. Codelfa-Cogefar continued to experience very bad conditions in the tunnel in 1972, but conditions improved the following year and seven and a half miles had been driven by early 1974. By this time the Mangaio tunnel was nearly driven through.

In early 1975 there were still two and a half miles of the Moawhango tunnel to be driven. Work had been going well on the Mangaio tunnel when, without warning, at 4 a.m. on 24 April, a lahar swept down the Whangaehu River from the crater lake on Ruapehu, burst the river banks at the tunnel entrance and swept rock, mud and water into the tunnel. Fortunately the men were out of the tunnel for 'smoko'. The mudflow, which continued for about two hours, destroyed



Right: An Italian construction firm, Codelfa-Cogefar, won contracts for the three long Tongariro development tunnels and imported many skilled Italian tunnellers. Here some of them pose beneath the Moawhango tunnel portal, which has their patron saint, Santa Barbara, above it for protection.

New Zealand's Latest Power Story — Tongariro Power Development, Ministry of Works and Development, 1974 equipment and huts and left behind a great mess including large boulders, but did no damage to the tunnel itself. The failure of the early-warning system for the Whangaehu River and the speed of the lahar made better protection of Lake Moawhango imperative, and a permanent stop-bank was built on the western bank of the Whangaehu. The dam, the Wahianoa aqueduct and the Mangaio tunnel were all completed in 1975. The Moawhango tunnel was finally holed-through on 29 May 1976, but much concrete lining was still required. This work continued for the next three years.

The Moawhango dam was filled in April 1979, and the Eastern Diversion was commissioned in September. In December 1979 the feast of Santa Barbara was celebrated with the commissioning of the Moawhango tunnel and the unveiling of a plaque commemorating the work done by Codelfa-Cogefar by the Prime Minister, Robert Muldoon. Muldoon used the occasion to pay tribute to the successful co-operation of the Ministry of Works and the contractors, and to the role of the New Zealand Workers' Union. Given the dangers, the safety record underground and indeed on the whole project was quite remarkable. The first fatality for the entire development occurred above ground in 1968, four years after work had started; there were to be only two deaths in tunnels, and none in the very difficult Moawhango tunnel.

The Rangipo power station is a run-of-river station because of the lack of storage capacity. About two-fifths of the flow comes from the Tongariro River, a third from the Moawhango diversion and a quarter from the Waihohonu diversion. This part of the development was investigated and designed by the Ministry of Works. Because of the high cost, it was decided to assess the experience of the Moawhango tunnel before making a final commitment to proceed with Rangipo, which was eventually recommended by the Power Planning Committee in 1972. Its revival roused the Tongariro and Lake Taupo Anglers Club to renewed action. The Wildlife Branch of Internal Affairs again kept a watchful eye on the rivers for any impact on trout. While acknowledging the trouble that had been taken to keep 1,000 cusecs in the Tongariro River, the Wildlife Branch feared that fluctuating water levels downstream from the Rangipo station might undo the good work.

Rangipo was the first part of the Tongariro development to be assessed by an Environmental Impact Report, which was submitted in July 1973. The Commission for the Environment felt that insufficient attention had been given to fisheries, and recommended consultation with the New Zealand Forest Service about activities in the Kaimanawa Forest Park area, and with the Wildlife Branch in matters affecting fishing. Rangipo was approved in November 1973, with an estimated commissioning date of April 1980. Preliminary work started straight away.

By September 1975 the Ministry of Works and Development had begun the access tunnel to the underground powerhouse, and in October Codelfa-Cogefar got the contract to build the headrace tunnel. The Moawhango tunnel workforce could now transfer to the new tunnel. By early 1979 nearly two-thirds of this had been driven, but difficult conditions had again been met. The tunnel was holed-through in 1980. The powerhouse access tunnel had been finished in 1976, when work began on the powerhouse and surge chamber caverns. Excavation of the caverns was completed and lining began in 1978. Good progress was made on the Rangipo intake dam at this time.

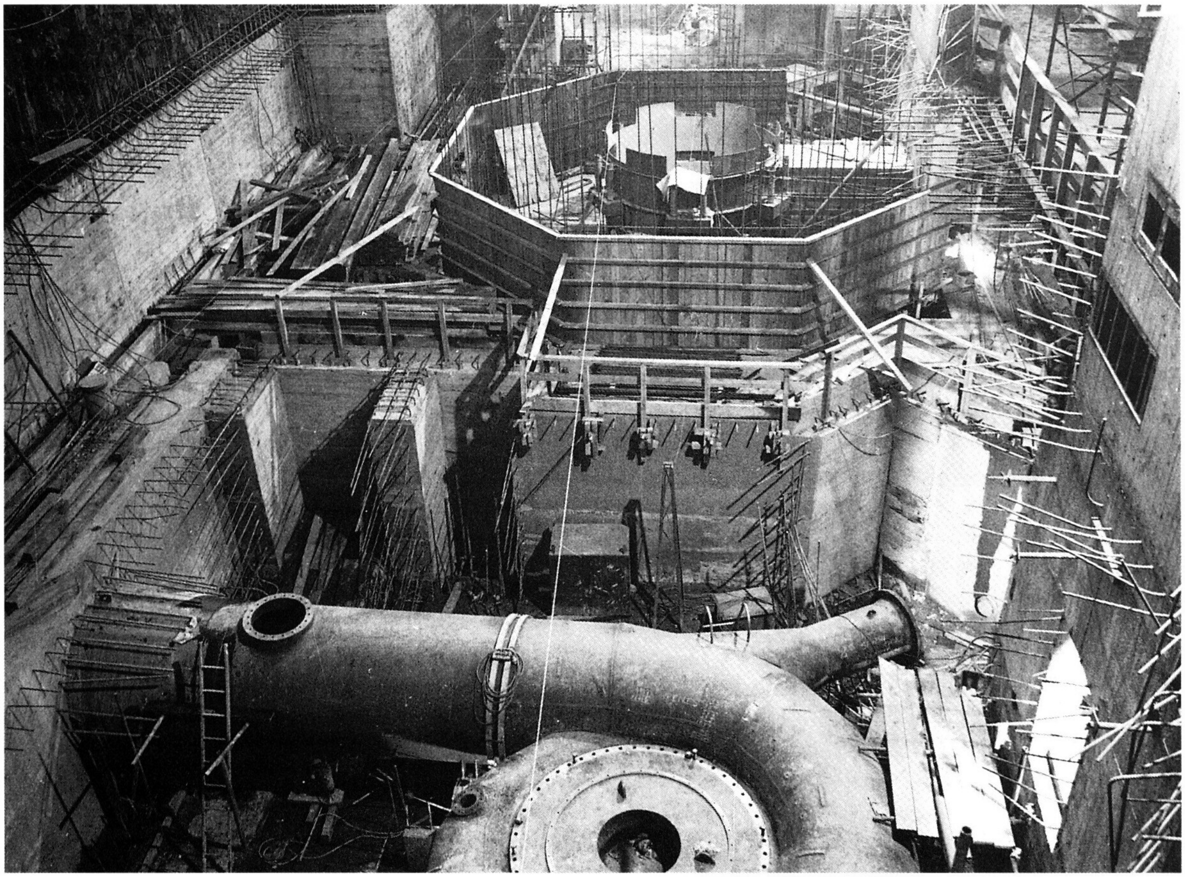
By early 1979 the Rangipo scheme was half complete. Work was now concentrated on the intake dam, where half of the concreting had been done, and on the underground powerhouse, which had been lined and where the penstock tunnels and shafts were being excavated. The Tongariro River was diverted in March 1980 to allow completion of the dam, which was finished in November 1982.

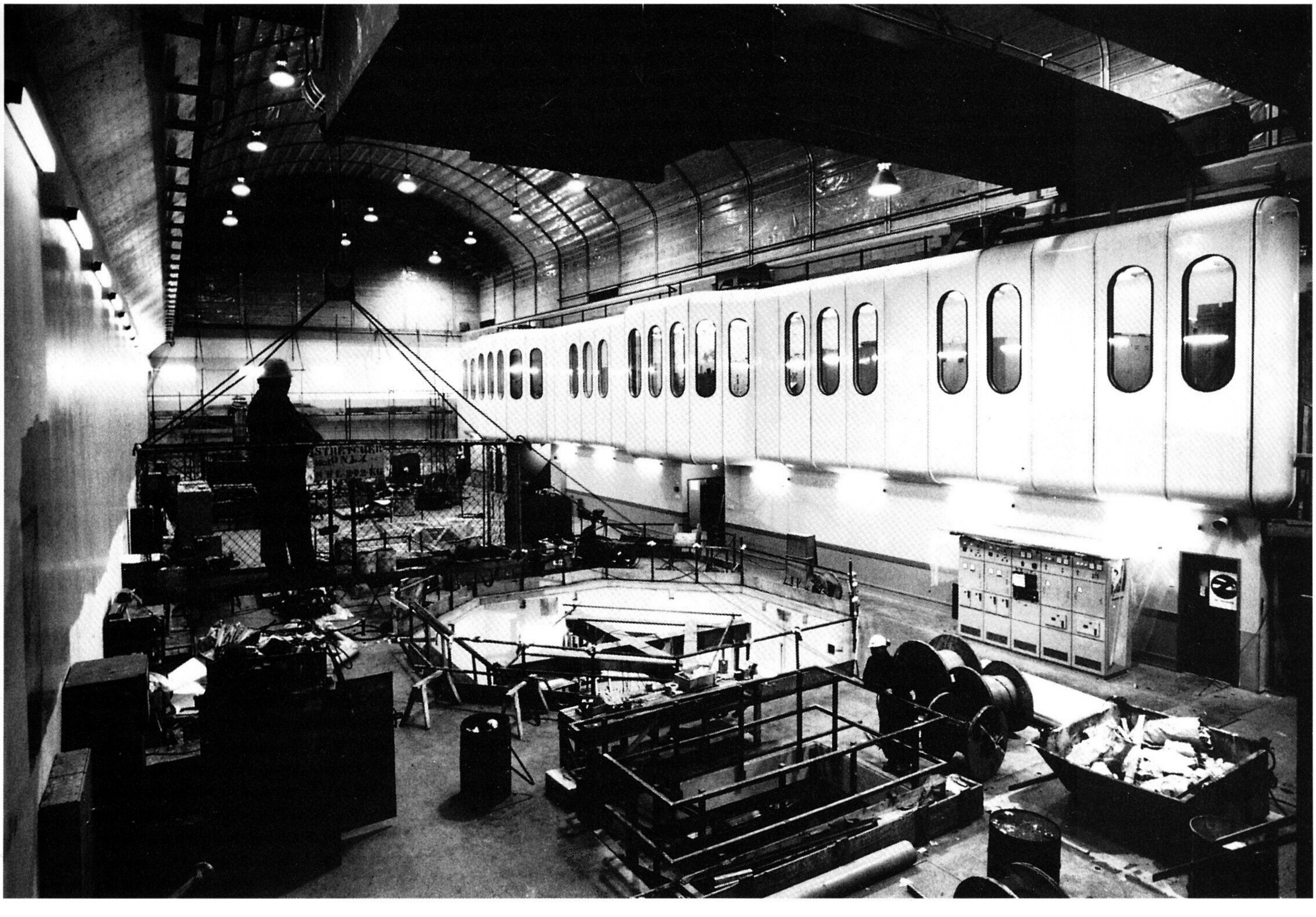
The last remaining link was the tailrace tunnel to the Tongariro River at Beggs Pool. Downers got this final contract in 1977, with a completion date of October 1981. By early 1979 one-third of its length had been driven, but the tunnel had to be realigned after unsuitable broken rock was encountered. It was eventually holed-through in April 1981. The Waihohonu tunnel was driven by the Ministry of Works and Development between August 1980 and November 1981 and commissioned the following November.

Shortage of funds and design delays meant that

Opposite above: The Rangipo powerhouse, 80 metres underground, is shown here during the installation of scroll casings and the concreting of a generator enclosure.

Opposite below: The almost-completed Rangipo powerhouse, with the elevated control room to the right. The station, which was opened in 1984, is remote-controlled from Tokaanu.





the Rangipo power station was not completed until March 1983. The last two years of work were punctuated by delays in the completion of the headrace and tailrace tunnels and in the delivery of electrical equipment from India. Installation of the first machine began in 1981 and was completed the following year. During November–December 1982 the Rangipo dam was filled temporarily for testing. The Waihohonu Stream was then diverted, and the dam was refilled in January 1983. Almost all the Rangipo work, including all shafts and tunnels associated with the powerhouse, was completed by March 1983. It remained only to commission the machines and construct the Waihohonu dam, which was largely completed in 1984.

The commissioning of the first generator took until May 1983. There were problems in the drainage system in the powerhouse, and the operators complained of noise and poor ventilation and took industrial action. The second generator was delayed by the late delivery of equipment, and it was commissioned in November 1984 at the same time as the station was officially opened.

This most complex project was finished at last, twenty years after it had been approved. It had given a considerable boost to the town of Turangi and opened up many previously inaccessible areas. Because much of the scheme involves tunnels, its visual impact is surprisingly slight for such a large development. Land that had been disturbed by construction was soon carefully replanted. The Department of Lands and Survey provided native grasses and shrubs which were planted on more than 200 kilometres of embankments and earthworks.

In recent years the amount of water diverted from the headwaters of the Wanganui River has come under scrutiny because of concerns about possible impacts on wildlife and navigation in the Whakapapa and Wanganui Rivers. Since 1983 a slightly reduced mean flow of 20.6 cumecs has been diverted. In 1988 the Rangitikei-Wanganui Regional Water Board sought to reduce this figure to 14.6 cumecs, and in October 1990 the Planning Tribunal decided that only 17.6 cumecs could be diverted. The Electricity Corporation is currently appealing in the High Court against this decision. This reduction would decrease the energy generated in the Tokaanu and Waikato power stations by 120 GWh a year and necessitate increased use of thermal power stations.

CHAPTER TWELVE

Thermal Generation

MANY OF THE EARLY local power plants generated electricity thermally by means of steam or by the combustion of gas or oil. At that time it was difficult to utilise hydro-electric resources for many purposes because electricity could not be transmitted over long distances. Once the transmission problem was overcome and the state became involved, hydro-electric stations soon dominated the scene. From the mid-1950s onwards, however, with the Waikato River fully committed and other North Island hydro-electric resources either not investigated or apparently too expensive, the government began to consider large-scale thermal generation seriously. This was to change the shape of electricity generation in New Zealand, particularly after the discovery of natural gas in the 1960s. The forerunner of these developments was the coal-fired station at Meremere.

Meremere

In the 1950s the new team of Goosman and Davenport was less hostile towards the idea of thermal generation than Semple and Kissel had been. They believed that demand was likely to continue to spiral upwards for a long time and were acutely aware of the limited extent of the North Island hydro-electric resources that remained unexploited. On the other hand, it was unclear whether sufficient coal would be available for a large steam plant. The use of South Island coal in the North was thought unattractive, and the Mines Department was not very interested in establishing the extent of available resources, simply asserting that there would be no need for Waikato coal beyond existing demands for many years. Goosman wanted to find an opencast mine that would last for 60 years.

Meremere: Constructed 1956–58. The first major thermal station in New Zealand. The plant beside the Waikato River has used up to 800,000 tons of coal a year, most of it until recently transported by a 6-mile aerial ropeway from the Maramarua field across a swamp. The coal is pulverised into powder and blown into six boilers, which can produce 300,000 lb of superheated steam an hour at 865°F and a pressure of 640 psi. The steam was originally fed into six turbo-alternators each generating 30 MW. A seventh turbo-alternator was added in 1967 to utilise the overload capacity of the existing boilers. The waste gases go through electrostatic precipitators before being discharged through 150-foot-high chimneys. Up to 30 million cubic feet of water a day is drawn from the Waikato River for condensing steam and cooling the plant. Total capacity is 210 MW.

In July 1952 Preece, Cardew and Rider were asked to report on the feasibility of a 100 MW base-load thermal plant. The consultants considered the use of oil, but quickly decided against it. The government made it clear that its preferred option was to develop the coal reserves at Maramarua, even though the greater part of the field was in private hands. Glen Afton Collieries, a subsidiary of the New Zealand Co-operative Dairy Company, used the coal to produce power for its own factories. Preece, Cardew and Rider's 'London Report' of December 1952 suggested that the station could be located either on the coalfield itself or beside the Waikato River near Mercer. (Meremere became the official name for this station in 1958.) The latter site would be more economical because it would allow the use of river water rather than cooling towers for cooling. The report also recommended that four 30 MW units be installed, with possible expansion to 180 MW.

The London Report was not immediately acted on, because of the competing attractions of the geothermal resource at Wairakei and a reluctance to accept the high operating costs of a coal-fired station. But Wairakei became more problematic and was delayed for a time, so in 1955 the Combined Committee dusted off the report, recommended that it be brought up to date and advocated the building in the Waikato of a 120 MW station. The government approved this, and Cabinet set up an inter-departmental committee, on which Mines was not represented, to look into the question of its siting. This committee recommended the use of Huntly coal, largely for social reasons. But Glen Afton's manager seized the Minister's ear and painted an alarming picture of the exhaustion of high-grade Huntly coal within 25 to 30 years, while Glen Afton and the state held at Maramarua very large reserves of lower-quality coal suitable for a power station. The need for Glen Afton coal would be even greater if the station's capacity was to be 180 MW.

The contract for design of the station and supervision of the project was let to Preece, Cardew and Rider, and that for civil-engineering design work to Sir Alexander Gibb and Partners. The main construction contract was let to Morrison Knudsen and H. K. Ferguson of the United States in partnership with Downers of New Zealand.

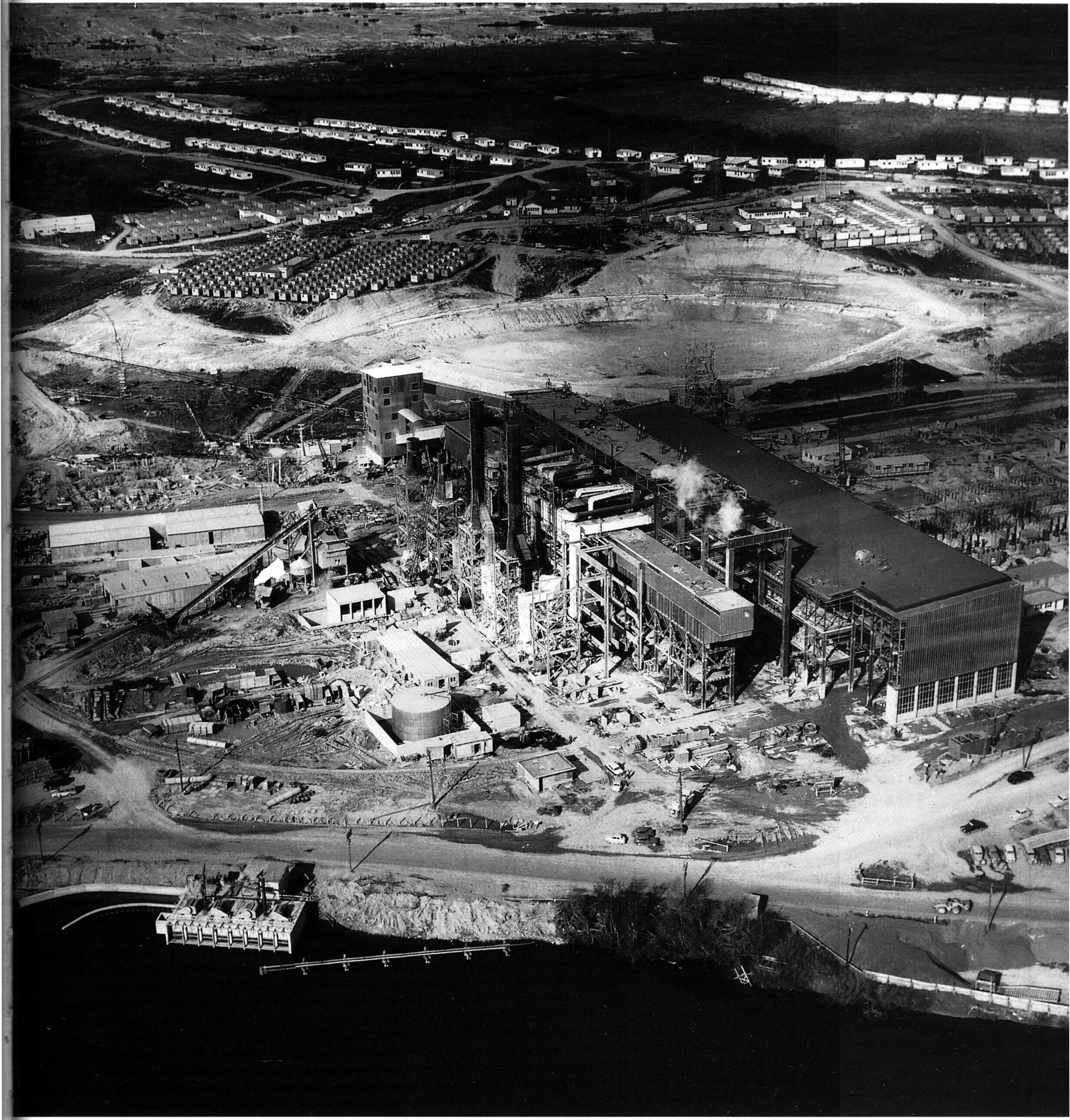
Meremere was the first major thermal station in this country, and although it was not an advanced plant for its time, its 1930s technology had a long-proven record overseas. There were to be six boilers feeding into a common steam main supplying six turbines driving 30 MW generators. The units were of a standard size and familiar in the industry; it was decided not to try to obtain more advanced high-pressure boilers coupled to large units. The State Hydro-electric Department was well aware that it lacked the expertise to operate and maintain high-pressure boilers, and that it would be very difficult to develop the required skills even under the careful tutelage of Preece, Cardew and Rider. Using conventional technology would also assist the rapid completion and commissioning of the project.

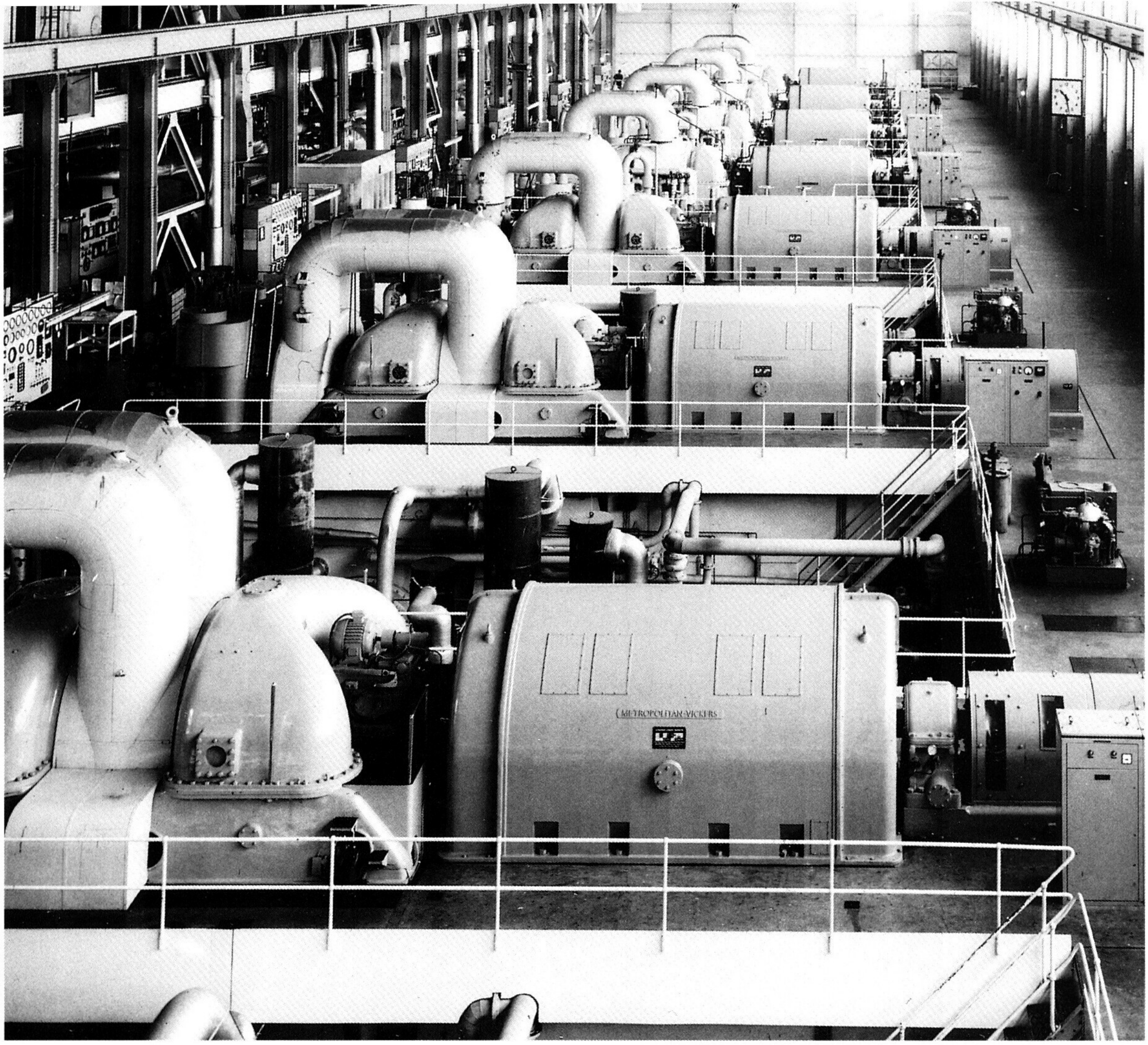
The coal was delivered by an aerial ropeway from the Maramarua field, which was six miles away across a swamp. It was crushed into chips, ground into a powder in pulverising mills and then blown by fans drawing air through heaters into the boilers for burning. The hot waste gases produced were led back to the air heaters and discharged to the chimneys through cyclone separators. Water was taken from the Waikato River for condensing the steam and for cooling purposes, and then returned to the river.

The Glen Afton company's initial opposition to a joint venture with the government for the supply of coal began to weaken, and early in 1957 it agreed to the formation of a joint company, Maramarua Coalfields. An agreement was signed in November 1957 for a supply of coal that would increase each year, but the price could not be agreed upon and was left to arbitration.

Meremere was due to be completed by October 1958 and was built quickly. Some 550 men were accommodated on site, where there was a single men's camp for 400, and about 150 houses, a recreation hall and a school. Good progress was made in 1956 despite three months' work being lost because of an extremely wet winter and a good deal of industrial trouble between the contractor and the labour force (which reached a peak of more than 1,000). Steelwork for the turbine house was being erected in February 1957, and for the boilers in April. By early 1958 the powerhouse and cooling-water culverts had been completed, the boilers were going up rapidly and two turbo-alternators were being installed. The first power from one unit was produced on 13 August 1958, slightly alleviating North Island power shortages, and the second unit came into use in October. By then all six machines were ready, but four still awaited their boilers. Until the ropeway was finished in May 1959, coal was railed from Huntly or brought by road from Maramarua. Meremere required a permanent staff of between 150 and 200 for its operation, and a substantial village was built to house them.

Opposite: Meremere, New Zealand's first large thermal station, was built beside the Waikato River near Mercer to use river water for cooling and coal from the Maramarua field. In this September 1958 photograph the powerhouse has been finished, the first two of the six chimneys have been erected, the water intake on the river has been finished, and the coal-stockpile area behind the station has been formed. Behind and above the station lie the public works camps and construction housing.
Whites Aviation





The seven 30 MW turbo-alternators inside the Meremere powerhouse.

One aspect of the Meremere station caused concern. Preece, Cardew and Rider, on the basis of tests done with pulverised British coal, had recommended the mechanical collection of the coarser particles produced and dispersal into the atmosphere of the residual fine dust ('fly ash'). The much softer Waikato coal had a higher proportion of very small particles, and the situation was made worse by the fact that Meremere's chimneys were only 150 feet high. The dust arrestors installed were therefore much less effective than had been expected.

By the mid-1970s the problem had become more pressing and more noticeable, particularly because the station's load factor was so high. Not only was much more coal being burned, but it was also very difficult to shut down boilers for long enough to clean them properly. Moreover, much of the coal now used had a very high ash content.

After the passage of the Clean Air Act in 1972, the department had to obtain a licence from the Minister of Health to operate Meremere outside its requirements. Government indifference to the standards at Meremere became a serious hindrance to the efforts of the Department of Health to enforce the Act. The example of Meremere was also a factor in objections to the siting of other, more modern thermal power stations. People did not believe that these would perform any differently.

The Department of Health was very dissatisfied with a statement by the Electricity Department in September 1975 that it would try to make the existing system work as well as possible by monitoring it and ensuring better combustion. It proved to be impossible to meet Health Department standards. The Electricity Department believed that the problem could not be solved without spending several million dollars, and did not think this was justified. While the Department of Health continued to press for improvements, the Electricity Department argued that Meremere was obsolescent, no longer essential, and used for only part of each year.

By 1978 there was growing indecision as to what to do with Meremere. The agreement for coal supply was about to run out, and it was likely that there would be a surplus of power for the next decade. In August it was decided to decommission Meremere over a five-year period.

In June 1981 there came an about-turn when the Cabinet Economic Committee supported a $20 million refurbishment that included the installation of electrostatic precipitators, which remove virtually all fly ash. Meremere could now be kept in operation until 1995. This change was associated with the major new energy development policy announced by the National government in 1980. Delays were also being experienced in the completion of the massive Huntly thermal station. Final approval for the refurbishment was given in October 1982, and the work was done gradually over the next four years.

In recent years Meremere has largely been used as a backup station, and for voltage support to the Auckland region. In March 1991 it was decided to 'mothball' the station indefinitely, because it has become increasingly uneconomical to run. Meremere might possibly be converted to a combined-cycle gas plant in the future.

Marsden A and B

By 1963 the Power Planning Committee was becoming concerned about Auckland's growing power needs, and the dramatic increase in the demand for electricity experienced in the year to March 1964 led inevitably to an upward revision of estimates, which now forecast serious 'dry year' deficiencies by 1967. Power was needed quickly, and, with the oil refinery built, the committee in 1964 recommended meeting the shortfall with a new 240 MW oil-fired station at Marsden Point (later known as Marsden A).[1] The first power was to be available from April 1967.

What was required was a simple, rugged, easy to operate and low-maintenance station that could help with peak winter loads and 'firm up' the load curve (i.e., make up for hydro-electric deficiencies when flows were low). The main task of Marsden A would be to run continuously over the winter months. The site was determined by the location of the oil refinery and the need for power north of Auckland. Oil-fired plant was the only type that might be ready in time, and its size was dictated by the amount of surplus residual oil that would otherwise be sent overseas.

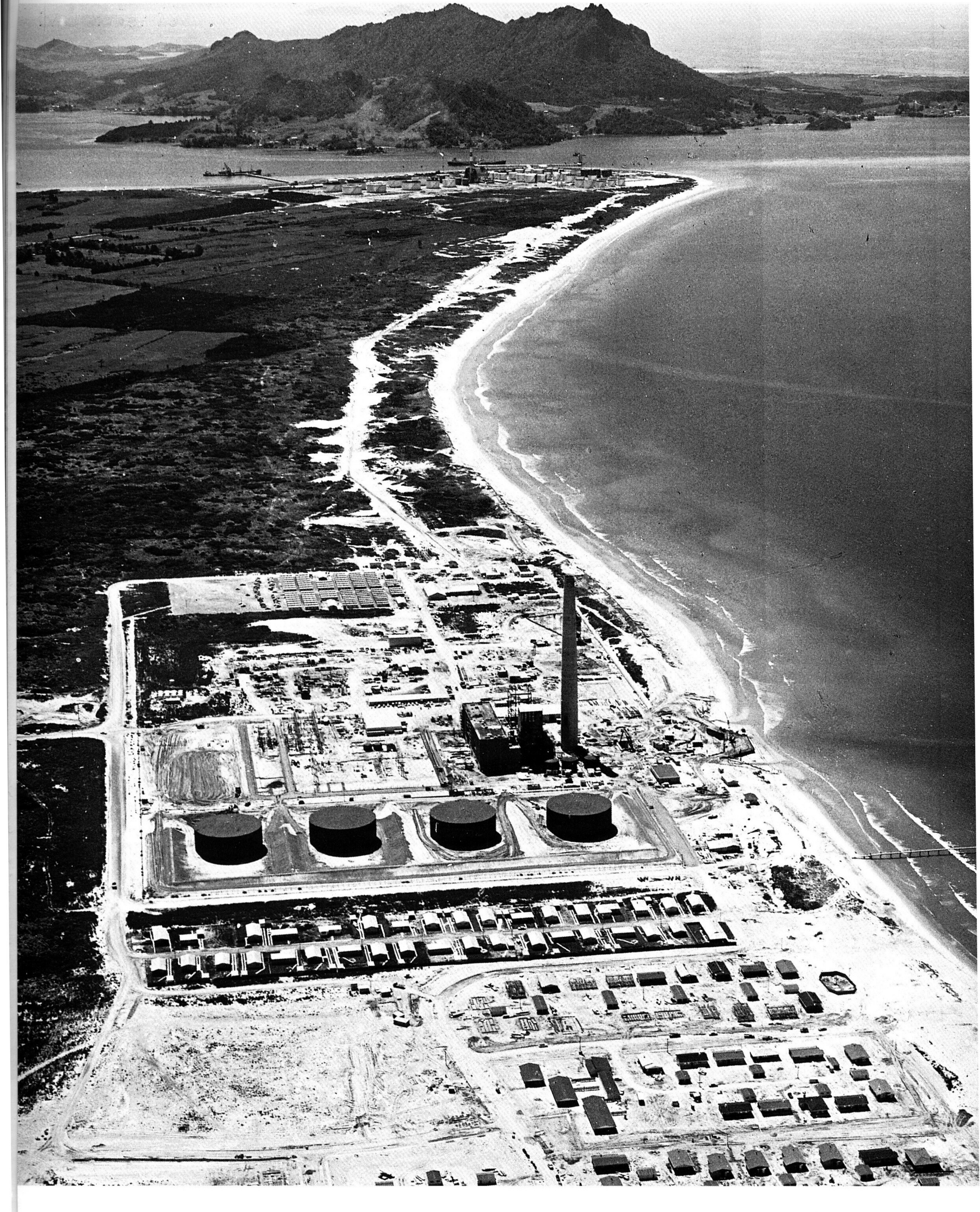
Overseas contractors were needed to design Marsden A. In September 1964 the Cabinet Works Committee rapidly approved in principle the construction of the station, and the use of Bechtel Corporation for its design, construction and commissioning, because Ministry of Works staff were not available. The approval to go ahead came in February 1965, and generating plant was quickly ordered. After initial consideration of a site closer to the refinery that proved unsuitable, the present site was chosen early in 1965. In May contracts were let to a consortium of Fletchers, Downers, and Wilkins and Davies, and work began. The chimney foundations were started at the end of 1965 and the chimney was finished by October 1966, while the turbine house was erected that year after some delays caused by labour disputes. At its peak the project employed 700 people.

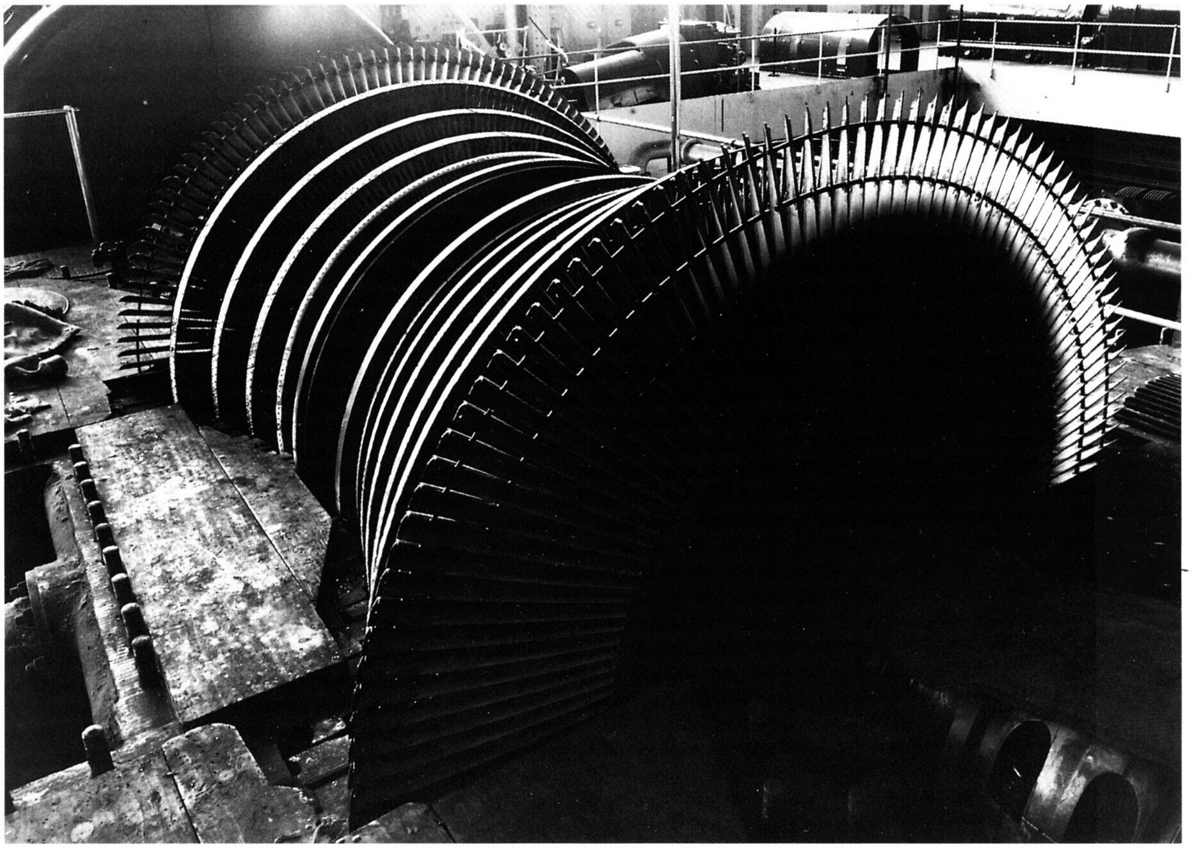
Power was available from the first unit in May 1967, less than two years after construction began. This was a considerable achievement by Bechtel. The first machine was commissioned on schedule and in time for the winter at the end of June 1967, and the second at the end of January 1968. While the station was being built, 220 kV lines were extended from Henderson north to Marsden and south to Otahuhu. Marsden soon proved its value, as the winter of 1969 saw water flows that, at about three-quarters of the average,

Marsden Point

Marsden A: Constructed 1965–67. Oil is piped 3 miles south from the Marsden Point refinery into four large storage tanks on site. Two boilers running on residual oil provide 985,000 lb per hour of steam at 1,000°F and 1,525 psi. Two 120 MW turbo-alternators give a total capacity of 240 MW. The plant is cooled by sea water supplied by a submarine concrete pipeline stretching 2,800 feet out into Bream Bay. Cooling water is returned to the sea by a culvert and pipeline 2,000 feet long. Its 400-foot-high and steel-lined reinforced-concrete chimney was at the time the highest in the country.

Marsden B: Constructed 1976–79. A boiler provides 820 tonnes of steam per hour at 541°C and 130 bar. A single 250 MW unit, designed to use residual heavy fuel oil, was installed but never run. Another 400-foot-high chimney and four more oil storage tanks were built.





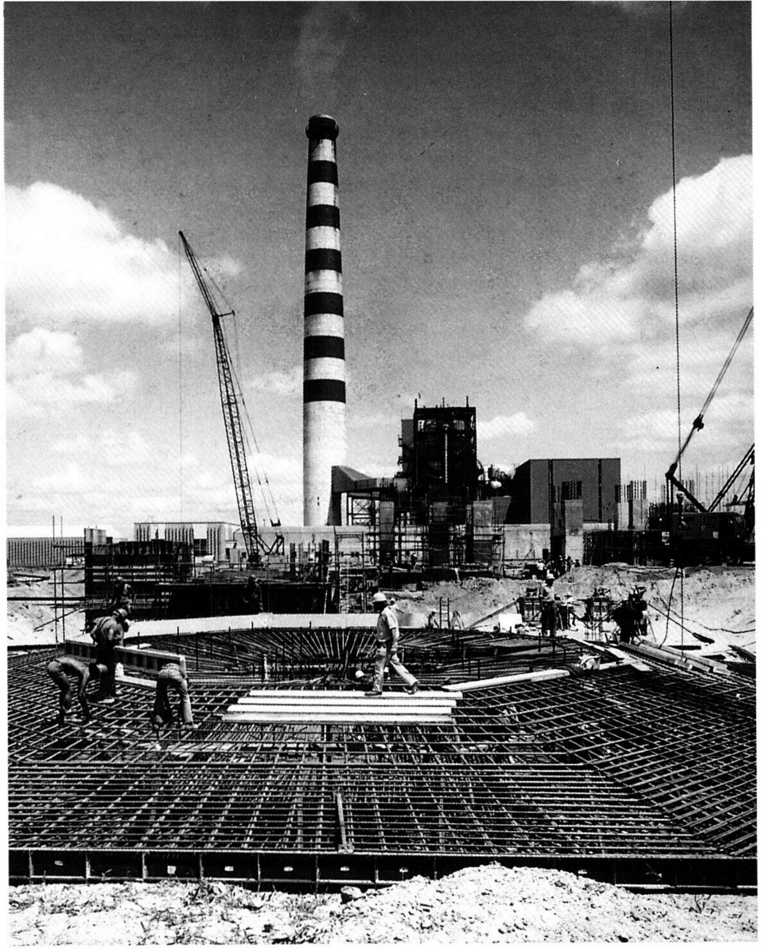
Above: Exposed turbine rotor blades at Marsden A.

were the lowest on record in both islands. Marsden and Meremere both operated continuously at full load, and were assisted by the first gas turbines of the new Otahuhu station. More recently Marsden A has been used for voltage support for the area north of Auckland, as well as assisting when water flows are low. One turbine has now been put into storage and its generator is used only for voltage support.

In 1972 the Power Planning Committee recommended that Marsden should have two more 250 MW base-load units from 1981, but the following year the proposal was altered to a single unit burning residual oil. This was to be in place by 1978 and was intended to cover peak loads and dry-year firming of load, because of lack of progress with the Upper Waitaki development, Huntly and Auckland Thermal No. 1. In 1974, because of the oil crisis, the specification was changed first to a more expensive dual-fuel plant burning oil or coal, and then later in the year back to oil because of the cost, increased construction time, uncertainty of supply and environmental effects of burning coal. Preliminary investigations began that year. Bechtel was given the job of designing the plant and managing its construction, and contracts for equipment were let in November 1975. The civil-engineering work was let to a New Zealand consortium, and the earthworks were completed in 1976. In the following two years progress was seriously hindered by industrial disputes, and commissioning had to be delayed. In 1978 the plant was almost complete and installation was proceeding. Further delay was caused by problems with the cooling system in 1979, but by then commissioning had begun. However, in June the government decided to mothball the plant because of its high running costs and the expectation of overcapacity in the next decade. Full commissioning was halted.

Investigations soon began as to whether the station could be run on coal, and then, as more gas

Opposite: The Marsden A power station was built south of the oil refinery at Marsden Point, near Whangarei. The line of the oil pipeline from the refinery to the station can be seen running along the sand dunes. This October 1966 photograph was taken when the 400-foot-high chimney had just been completed. This and the four oil-storage tanks dominate this view.



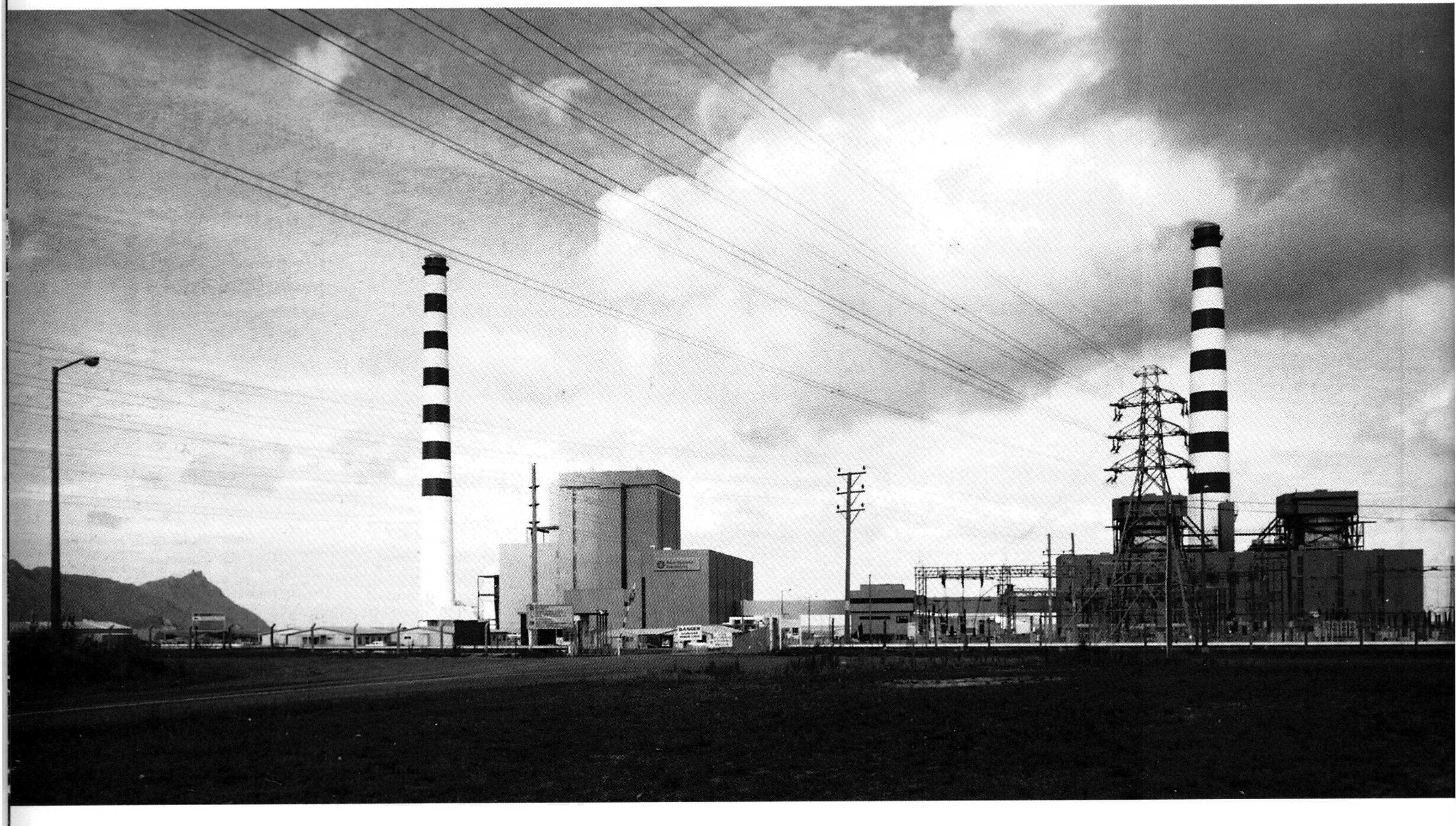
seemed likely to be available from 1985, into the cheaper possibility of converting it to burning gas, which would have enabled it to be used economically as a base-load station. Gas was recommended in the 1986 Energy Issues Paper, but, because of the now-limited resources of the Maui gas field, the use of coal is again being looked at, as is the possibility of using 'orimulsion' (an emulsion of bitumen and water).

New Plymouth

In 1964, which saw a huge rise in consumption, the Power Planning Committee began to consider a second coal-fired station and recommended that overseas consultants be engaged to report on a station using Buller coal, since at that time Waikato coal reserves were thought to be very limited.[2] Preece, Cardew and Rider, who were

Left: Foundations for the Marsden B chimney, and construction of the turbine house behind, are overshadowed by Marsden A's chimney.

Below: The two completed stations, Marsden A and B, with Marsden B's single turbine house on the left.



highly regarded for their work at Meremere, were asked to undertake this task. The consultants' brief left open the question of a site. There were political pressures to use Buller coal, and the station of perhaps 500 MW was to supply the southern part of the North Island. Sites near Wellington and at Wanganui and New Plymouth were contenders. New Plymouth was less favoured from the transmission point of view, since Taranaki itself did not need a large station.

It soon became clear that only Wanganui and New Plymouth were feasible, because of public opposition to the Wellington sites. There was also much expert concern about pollution at all the proposed sites because of the high sulphur content of Buller coal. The only means of dispersing it was through chimneys 500 or 600 feet high. The consultants in 1966 strongly recommended a 600 MW station at New Plymouth, on the grounds of its harbour and the absence of any restrictions on chimney height. The port's bulk-handling facilities for coal were also an important consideration.

In the same year the Power Planning Committee recommended that a station, which would produce its first power in 1972, should be built at New Plymouth. The committee took care to discuss the comparative economics of hydro-electricity and thermal generation, and asserted the long-term benefits of the former. It recommended New Plymouth out of necessity, largely because its construction costs would be lower than those of hydro-electric plant, but also because of a shortage of labour and the current state of investigations into hydro-electric schemes. The station would be more of a base-load plant than Marsden was intended to be. Commissioning in 1972 would allow enough time for site and wind-tunnel tests to ensure that the Health Department's emission standards could be met.

About half of the capital cost of the project would have to be found in overseas funds. Treasury argued for a delay on the basis that demand was not increasing in line with previous estimates. In November 1967 Cabinet approved the project in principle only and decided that construction could be delayed for a year. Tom Shand decided on the New Plymouth site in December 1967 after he, the Minister of Finance, Robert Muldoon, and the Minister of Works, Percy Allen, had considered further departmental reports. The harbour bar at Wanganui proved critical to the decision, and possible interference with Wanganui airport by the power station chimney was another factor. Wanganui was desperate for the station, and there were strong protests and a petition against the decision.

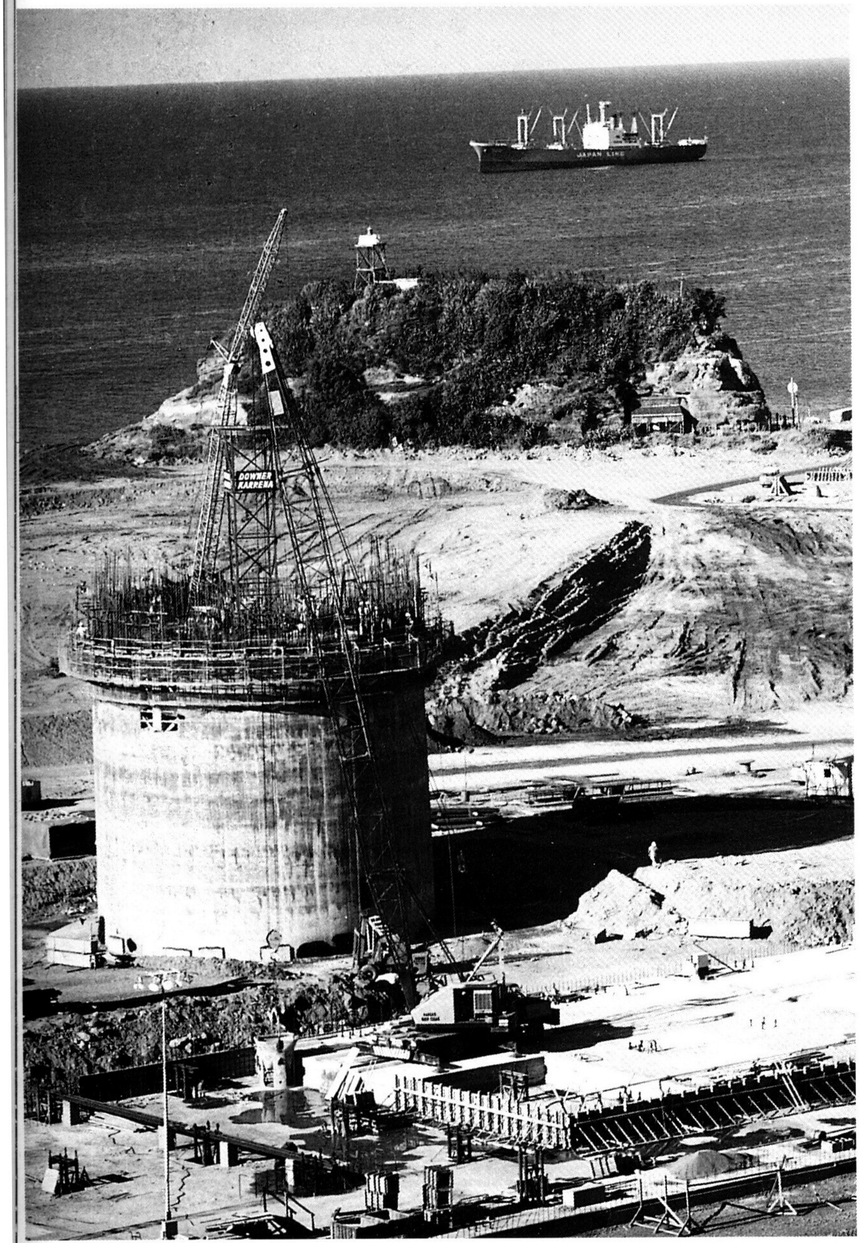
New Plymouth: Constructed 1968–74. New Zealand's second largest thermal station, it has run largely on natural gas but also on oil in its early years. The boilers produce 840,000 lb per hour of steam at a pressure of 1,800 psi and 1005°F. Five 120 MW turbo-alternators generate a total of 600 MW. The plant is cooled by sea water, some 55,000 gallons per minute being required on full load. The switchgear and other electrical equipment are totally enclosed to protect them against salt spray. There are three large oil storage tanks now used only in emergencies. The reinforced-concrete chimney is one of the tallest in the country, at 650 feet. It has five brick flues inside a concrete wind-shield.

In July 1968 Cabinet agreed to wait for an assessment of the growth of demand over the winter. Meanwhile, preparatory work began on the site, including the reclamation of fifteen acres by the Taranaki Harbours Board.

In December 1968 Cabinet approved the station and agreed that tenders could be called for the supply of turbo-alternators and steam-raising units. This process had potential political implications. Japan was becoming an important trading partner, and the contract to supply the turbo-alternators was sought keenly by both Japanese and British manufacturers. In the event, the Japanese machine on offer turned out to be unsuitable in that it was designed for continuous running. New Plymouth was intended to run only on two shifts and would need plant designed for greater flexibility.

Until now the debate over the use of natural gas (see the section on gas-turbine stations pp. 246–50) had had no impact on New Plymouth, but by 1969 consideration was being given to two of its units being fuelled by gas. By now the wider potential of the Taranaki offshore fields was being appreciated, the Maui gas field having been discovered that year. The major reason for suggesting that gas be used for only two units was to avoid too great a negative impact on the Buller region by reducing the demand for coal below 650,000 tons a year.

The estimate of 650,000 tons of coal was soon cut to 500,000. That seems to have been the bottom line for Shand, who stated in Parliament several times that this figure would not be lowered. But others were turning increasingly towards a greater use of gas. By the end of 1969 the consortium developing the Maui field had raised the possibility of running New Plymouth entirely on gas, while indicating that even this level of demand would not in itself merit the development of the field. Much of the discussion took place in an Officials Committee on the Oil Industry set up in February 1970. The Electricity Department itself was losing any enthusiasm for coal.



By April 1970 the department strongly preferred dropping coal. Large capital savings could be made on boilers and steel, and there would be no need for electrostatic precipitators or coal-handling equipment. The uncertainty associated with the delivery by sea of Buller coal would also be avoided. When it came to the point the government did not find it hard to break Shand's promises (he had died late in 1969). In May 1970 it decided to change to an oil-gas design that would operate mainly on oil, with gas perhaps ultimately taking its place.

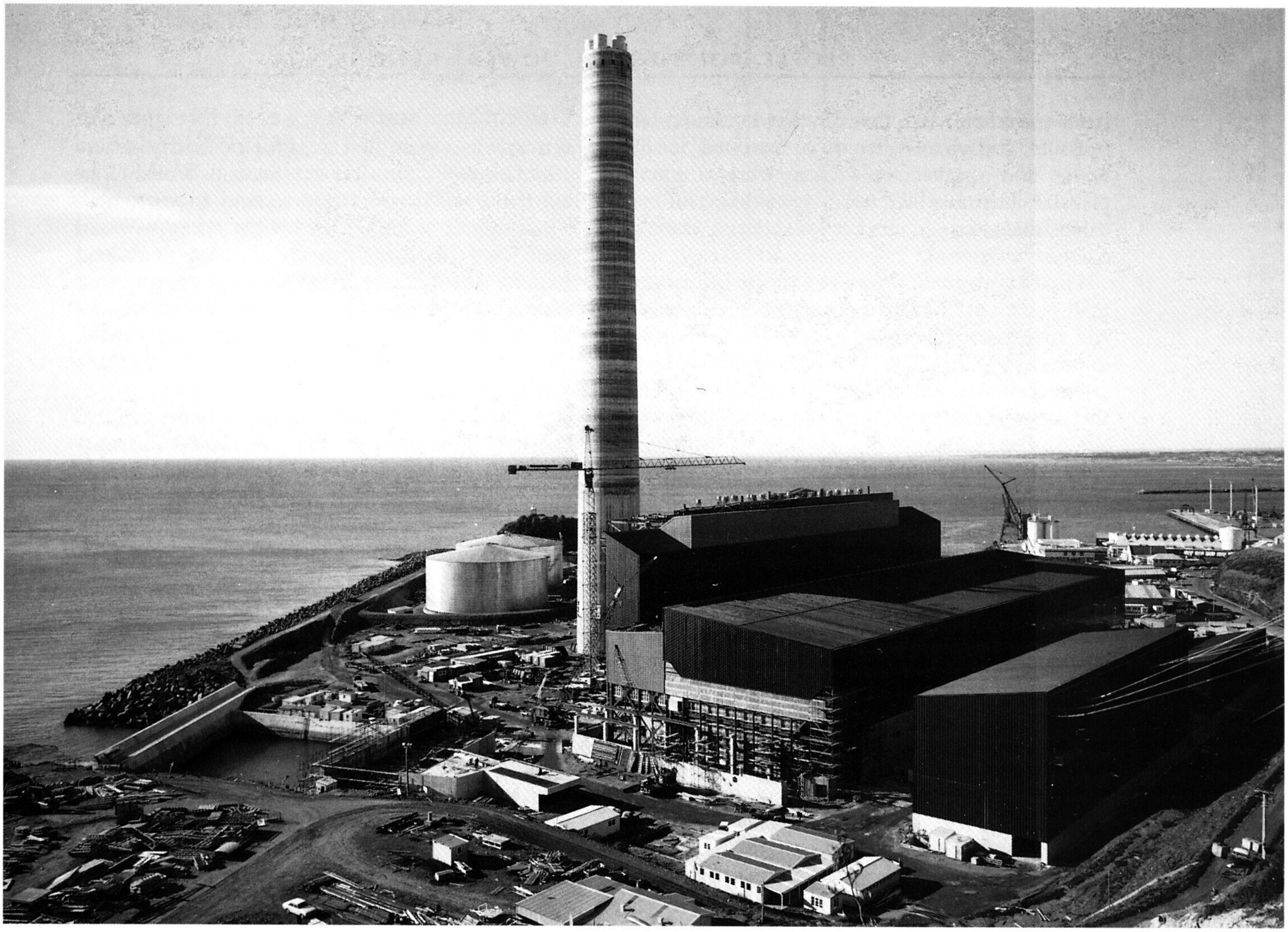
Agreement on the use of Maui gas for New Plymouth, Huntly and two power stations planned for Auckland was finally reached in April 1973 after some hard negotiating, on the assumption that an eventual 17,600 GWh and 3,300 MW would be generated by these means. The use of gas for electricity generation was a controversial issue, and was associated with fierce environmental battles over the two proposed Auckland thermal stations. The Maui contract was signed on 1 October 1973, together with the 'Acceleration of Kapuni Gas Purchase Contract' which incorporated the supply of the New Plymouth station. A pipeline would be needed. When the first oil crisis hit at the end of the year the policy became one of conversion to gas as soon as possible, with Kapuni gas to be used until 1978 and Maui gas thereafter.

The project generally went smoothly, with harmonious labour relations and a good safety record. Preece, Cardew and Rider supervised the project and did much of the mechanical and electrical design, while the Ministry of Works was in charge of much of the civil design. The Electricity Department and the Ministry of Works assumed joint responsibility for construction in a single project organisation. This innovation proved to be highly successful. It had been expected that hundreds of construction workers would come

Left: The chimney for the New Plymouth station goes up, and the powerhouse foundations have been begun, early in 1971.

Opposite above: The virtually completed New Plymouth power station with its 650-foot-high chimney. To the left the oil-storage tanks have been built on reclaimed land.

Opposite below: Inside the New Plymouth powerhouse, installation of the 120 MW turbo-alternators proceeds. In front the high- and medium-pressure sections of a turbine are exposed. The low-pressure section is to the right.



from elsewhere, but this did not eventuate and most of the work-force was recruited locally. Some 800 single men's huts were originally planned, but only 400 were provided, and only half of these were in fact occupied during the peak period.

The Ministry of Works began the preparation of foundations for the storage tanks and turbine and switchgear houses in July 1969. Work began in earnest in mid-1970 with a start on the foundations for the huge chimney, which was designed and constructed by Kareena, a German firm. The chimney was moved closer to the station when coal-handling equipment was no longer required, and foundations were begun again in August. In February 1971 the first concrete for the windshield was poured, and it was finished in April after a complex tapering slip-forming method of construction. The 650-foot-high chimney was specially designed, with multiple flues to disperse gases under widely varying loads.

The need to redesign the boilers imposed considerable delays. Fletchers, as a subcontractor to an English firm, began constructing the boilerhouse and installing the boilers in July 1971. The work-force reached a peak of 1,000 at the end of that year. There was also a ten-month delay in the delivery of structural steel from India. By early 1972 almost all the concreting had been done, steelwork erection was proceeding rapidly, the switchhouse had been completed and the first boiler was being erected. The turbo-alternators were installed in 1972–73 and the boilerhouse was completed in early 1974. By February 1974 one unit was generating electricity while the other four were in the final stages of installation. The first unit was commissioned in March 1974, the second in October and the other three during 1975–76. The station had an operating staff of about 300. After a major explosion in a furnace in July 1976, which damaged one boiler and its flue, modifications were made to the boilers and to operating procedures.

For the first two years mostly oil was used. The first two units were designed to use oil but were subsequently modified for gas. By the time the station was officially opened in March 1977 all units could use gas. Kapuni gas was first used in September 1975, and Maui gas in late 1979.

Gas-turbine stations

Gas turbines were first used for electricity generation immediately after the Second World War, by Brown-Boveri of Switzerland in particular. Their appeal was that they were cheap to build and were ideal for emergency and peak-load standby use because of their rapid starting and loading capabilities. They can thus make a significant contribution even if used only infrequently. They can also be used as synchronous condensers for voltage control.

As early as 1955 the Electricity Department had considered gas turbines and the Combined Committee on the North Island Electric Power Supply had recommended that three 20 MW units be built at Korokoro in 1958. Preece, Cardew and Rider prepared a report on such a plant that year. Orders were about to be placed when the government changed in 1960 and the proposal was dropped. It was resurrected by the Power Planning Committee in 1963 after much discussion on the use of the recently discovered Kapuni gas.

In 1959 a consortium looking for oil had found instead the large Kapuni gas field in Taranaki. In February 1962 the consortium suggested that Meremere might use the gas for five years, but the government was not enthusiastic about this. In March 1963 the Ministry of Works prepared a report on the use of gas for electricity generation

Gas-turbine Stations

Otahuhu: Constructed 1966–70. The first large gas-turbine plant in Australasia, it has four 45 MW Swedish Stal-Laval industrial gas turbines with intercoolers. Two further American Curtiss Wright 46.75 MW machines were added in 1977–78, making the total capacity 273.5 MW. The later units are derived from aero gas turbines and have the major advantage that they can be started up in minutes. The gas turbines draw in large masses of air through filtered intakes. After burning, the gases are exhausted through 200-foot-high stacks fitted with silencers. Two tanks provide storage for diesel oil.

Stratford: Constructed 1975–76. Four Pratt and Whitney aero-derived 55 MW gas turbines used initially Kapuni and later Maui and Waihapa gas. Total capacity is 220 MW.

Whirinaki: Constructed 1975–78. Four Pratt and Whitney aero-derived 55 MW gas turbines use diesel oil. Total capacity is 220 MW.

that suggested that a gas-fired station of 120 MW could be built in Taranaki. When the consortium said that it had abandoned as uneconomic all possible options except electricity generation, the Prime Minister replied in December 1963 that the government did not disagree strongly but would have to proceed carefully. The Power Planning Committee had that year proposed 120 MW of gas-turbine plant (the 'Kapuni' station) to be ready in 1968.

The government now commissioned a report by the American consultants, Zinder International, which was received in 1964. This was strongly in favour of the more efficient use of the gas as a 'premium fuel', by reticulation to Auckland, Wellington and seven other towns, rather than inefficient power generation. A Department of Scientific and Industrial Research paper of September 1964 suggested that it would be a mistake to fail to develop a modern gas industry because of the short-term needs of electricity supply. The 1964 Power Planning Committee repeated its recommendation for a Kapuni station initially burning gas, and perhaps later oil as other demand for gas developed, but the government deferred a decision until the question of the viability of gas as a premium fuel was resolved.

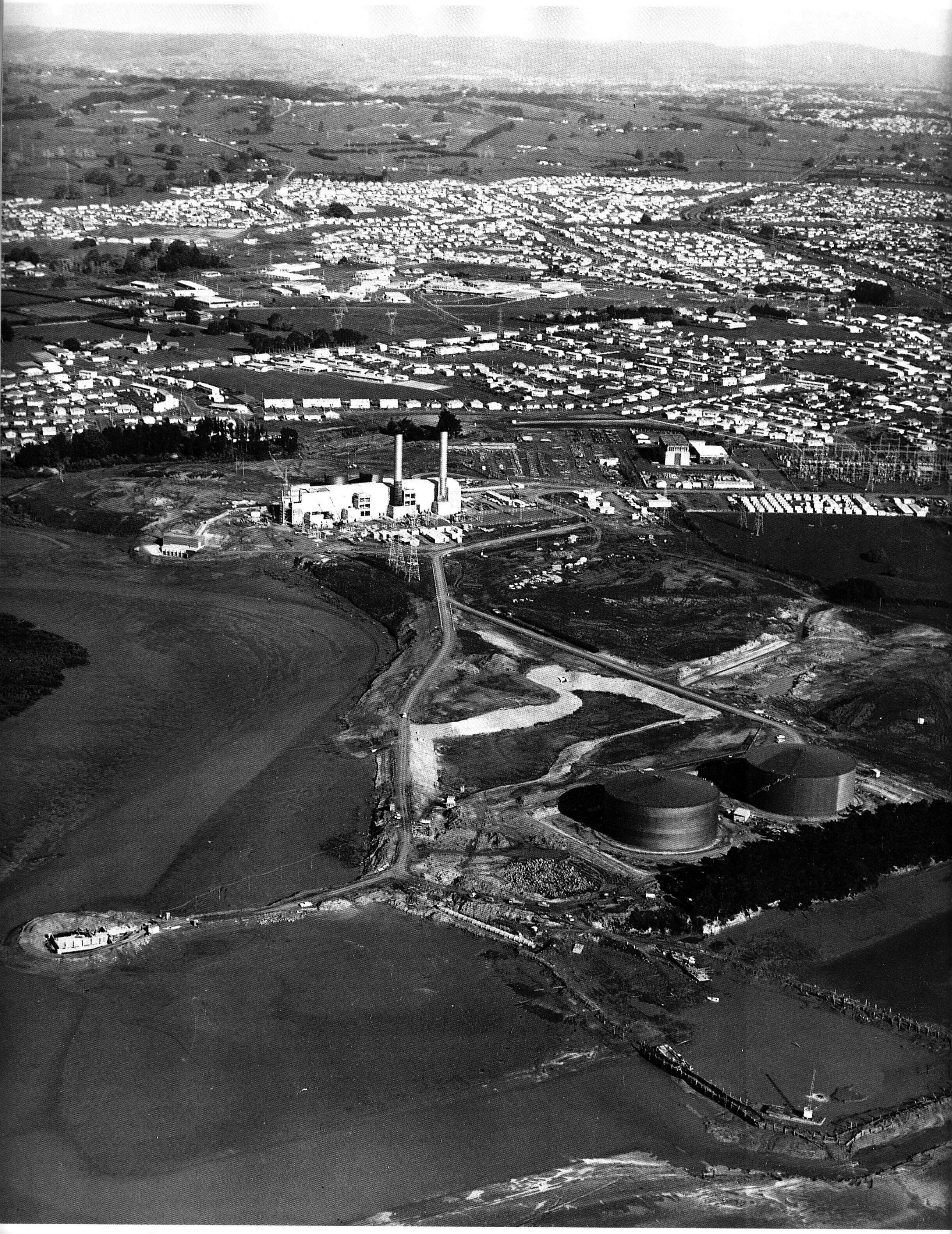
Still concerned about the potential shortfall, the 1965 Power Planning Committee recommended a further three 50 MW gas turbines, with an oil-fired one — perhaps at Wellington or Auckland — to be ready in April 1967, and the Kapuni station to be available a year later. Cabinet had in November 1964 approved the calling of tenders for three gas turbines in the expectation that Kapuni gas would be available. A fourth turbine was ordered subsequently. After some resistance Cabinet in September 1965 authorised the purchase of one unit to be installed at Otahuhu, and in November, after the second Zinder Report reaffirmed the first, approved three others for Auckland or Wellington, or Taranaki if it was not practicable to pipe gas to the cities. The Electricity Department soon decided that it wanted all four in Auckland, as the country's major load centre.

The Electricity Department had since 1945 held a considerable amount of land at Otahuhu.[3] In 1952 three synchronous condenser units were installed there for voltage control. When the question of the gas turbines came up, Otahuhu was in the department's view by far the best site, since it was in the middle of the greatest concentration of load in the country and a focal point in the transmission network. It was also well situated for the delivery of supplies of fuel oil and cooling water, and for a natural-gas pipeline. Another consideration was the desirability of having some power stations near the centres of load in large cities. Gas turbines seemed suitable for urban conditions: there would be no smoke or sulphur-dioxide emissions if natural gas was used, and little if the fuel was oil. The station would require no new transmission lines, an important factor in the crowded Auckland isthmus.

Nonetheless, a great deal of public hostility emerged when the proposals became known. This came from individuals, ratepayer associations and local bodies such as the Manukau City Council and the Auckland Regional Authority. In many meetings and statements Shand took on the impossible task of convincing them all that there must be some thermal stations in urban areas, and that these would not cause a major nuisance. Auckland would have to have either power stations or an undesirable network of transmission lines.

Public opinion would have none of this. People feared intolerable noise, widespread vibration through the foundations and the dispersal of tons of sulphur into the atmosphere. Many believed that coal was to be burned, and Meremere's pollution was cited as an example of what was to come. The Otara Ratepayers' Association appealed to the Ombudsman, who offered them little real comfort. A report on similar plants in other countries was, however, positive. At the quietest time of day the noise would be difficult to hear even 1,000 feet away, and the discharge would be no more than a heat shimmer except when the plant was being started up. The report urged landscaping to a high standard and, wherever possible, the allowing of public access.

Thus armed, Shand recommended Cabinet approval for immediate construction at Otahuhu, and this was given in June 1966. It would be the first large gas-turbine plant in Australasia. Site investigations had already been completed. The delay meant that there was now no chance of having a unit in operation by the following year as originally intended. Plant design was completed rapidly and contracts were let. The main building housing the turbines was designed carefully to minimise external noise. The four gas turbines were ordered and contractors began work on the four similar turbine-house units and the control block in December 1966. Four chimneys with an initial designed height of 100 feet were raised to 200 feet to minimise pollution. Two



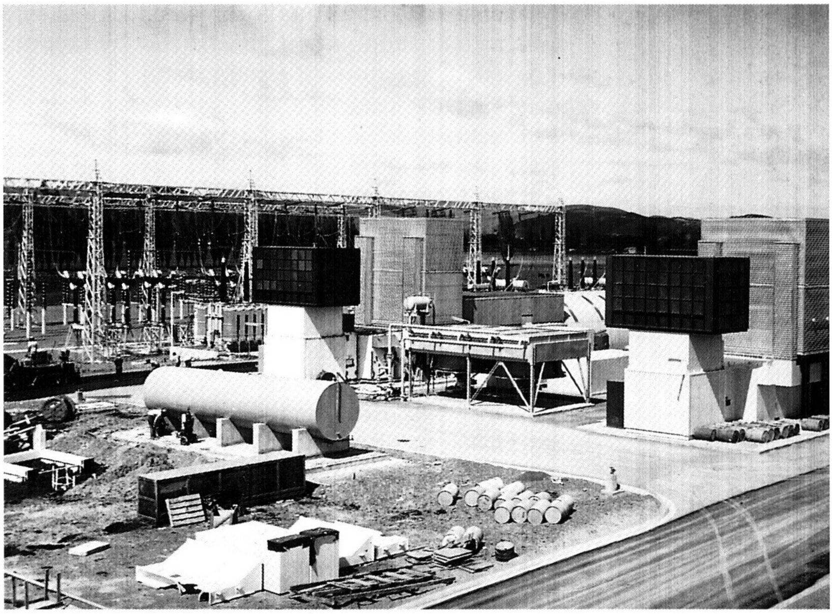
large fuel-storage tanks were also built. The plant was to be cooled by sea water taken from the ponded Otara Creek and discharged into the Tamaki Estuary. At first oil was to be brought by barge from Marsden Point, but in the event it was transported by road from Freemans Bay.

Otahuhu's first machine was commissioned in December 1968, the second in June 1969 and the last two shortly thereafter. The plant initially used Kapuni natural gas, but after industrial demand for this increased, it began to use more expensive diesel oil, which was burned only in emergencies. At first salt water was used for cooling the Stal-Laval machines, but this was largely replaced by a freshwater system. While it cannot be said that the Manukau City Council ever became enthusiastic about the station, there were few complaints about noise, vibration or pollution.

The contract for a 100 MW extension to Otahuhu was let following its approval in 1973, and in 1975 civil works began. The turbine building and two additional chimneys were erected in 1976–77. The first additional unit was commissioned in June 1977 and the second in December, but final commissioning was delayed because of the need for modifications. The plant was fully commissioned during 1978–79. In addition to emergency and peak usage, the plant helps with the control of voltage for Auckland.

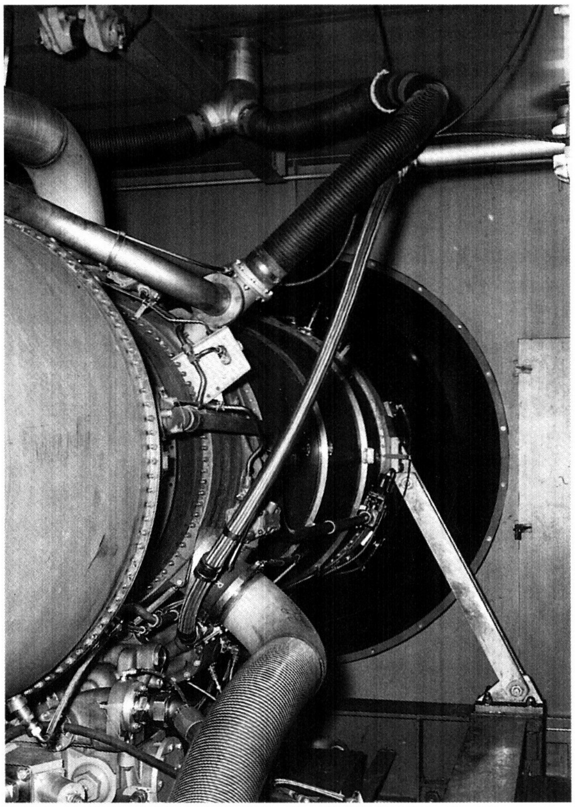
In 1973, in the context of a surge in demand, the Power Planning Committee had introduced the possibility of constructing packaged sets of gas turbines with a total of 320 MW capacity, since natural gas was readily available. Extra capacity was also needed while Lake Pukaki was being filled. By the following year Stratford and Whirinaki, which were existing substations, had been selected as sites for 220 MW stations in preference to various possibilities around Wellington and at Bunnythorpe, Meremere and New Plymouth. Approval was quickly given and contracts let for the units. Civil-engineering work began in 1975, and by the following year the Stratford station had been commissioned, with the units burning Kapuni gas. The first unit was

Opposite: This aerial view shows the almost-completed Otahuhu gas-turbine power station, with two of its initial four 200-foot-high chimneys installed. At first the plant was cooled by sea water taken from a ponded intake in Otara Creek (adjacent to the station) and discharged into the Tamaki Estuary at bottom left. Before long a freshwater cooling system replaced the salt water.
Auckland Star



Above: The Whirinaki gas-turbine station comprises four modular turbine houses containing 55 MW aero-derived engines which run on diesel oil. The air intakes and high silencer stacks for each module are a visual feature. The Stratford station is of similar design, with four turbines of the same kind, but runs on natural gas.

Below: One of the 55 MW Pratt and Whitney aero gas turbines installed at Whirinaki. The engines draw in a large mass of air through intakes fitted with filters, and the exhaust goes out stacks fitted with silencers. The entire turbine house is soundproofed to minimise the considerable noise.



commissioned in February, the second in March and the third and fourth in June 1976. Civil works at Whirinaki were half finished at that time. Two units were installed and commissioned at Whirinaki in 1977, and the other two the following year, but the plant had to await the completion of oil-supply facilities in 1978–79 before it could begin generating for the national grid.

Huntly

In 1969 the possibility of a serious supply shortfall of 250 MW a year developing between 1978 and 1981 was identified. In July 1970 Preece, Cardew and Rider reported to the government on the comparative economics of thermal and hydro-electric generation and nuclear generation.

There seemed to be two possibilities: a second station at Marsden Point or a coal-fired station near Huntly. The Mines Department now indicated that the Waikato's coal reserves were much larger than had been previously thought, and that there was enough good-quality low-sulphur coal to support a station of between 500 and 1,000 MW.

Preece, Cardew and Rider was asked in December 1971 to investigate three 250 MW coal-fired units at Huntly (with provision for a fourth unit) and two 250 MW oil-fired units at Marsden Point. The firm reported in March 1972 that both were feasible and that Huntly would be more economical, especially if the fourth unit was included. The station should be capable of using gas as well as coal. The Power Planning Committee of 1972 suggested that if the Maui negotiations were not concluded in time to allow plant to be ordered for Auckland Thermal No. 1 the following year, new projects would be necessary to meet the serious shortfall expected by 1978. Huntly was now recommended in place of the Auckland Thermal No. 1 station, which had been coming under increasingly heavy attack from environmental groups. The first 250 MW unit was to be available by April 1978.[4] Public discussions in the Huntly area had begun in September 1971, and in August 1972 a deputation from the Huntly Borough Council had urged approval of the station.

Since the Electricity Department did not have the resources to design and build a large thermal station, Preece, Cardew and Rider was engaged to help by seconding engineers. In August 1972 the Cabinet Works Committee approved in principle a 1,000 MW station at Huntly, subject to an Environmental Impact Statement. Environmental concerns and awareness had now increased considerably, in part because of the Tongariro scheme and the proposed Auckland Thermal No. 1 station. Huntly was the first major project for which the department had to produce such a statement, at a time when the procedures to be followed had not been fully developed. (The Commission for the Environment had been set up in 1972 by Cabinet directive.)

Huntly: Constructed 1973–83. New Zealand's largest power station, it generates more energy than all the Waikato hydro-electric stations together. Four 250 MW units give a total capacity of 1,000 MW. The boilers are the largest in New Zealand, weighing nearly 3,000 tonnes each. They operate at a steam pressure of 166 bar and a temperature of 538°C. Up to 700,000 tonnes of coal or 450 million cubic metres of gas a year can be used by each unit. The coal is delivered on a 3-kilometre-long conveyor belt from Huntly West mine and crushed at the station. Cooling requires 34,200 tonnes of water an hour, which is drawn from the Waikato River. Electrostatic precipitators are used for the removal of fly ash. There are two 150-metre-high chimneys, each with two internal flues.

The impact statement was published in June 1973 after drafts had circulated within the department between October 1972 and May 1973. In March 1973 the Waikato Valley Authority rejected an application for water rights for the project on the grounds that insufficient information had been provided, but water rights were subsequently granted by the National Water and Soil Conservation Authority in June 1973, subject to several conditions. The Electricity Department knew that if there was to be any hope of meeting the deadline tenders would have to be called at once, and asked for final Cabinet approval before the 28-day period for objections to the granting of water rights had expired. Approval to begin the project was given in August 1973, subject to a long list of environmental conditions and to the department allowing appeals against the complete project. These requirements were subsequently dropped. Objections to the water rights, including one from the local Maori communities, were heard in September and dismissed, although extra conditions were added to the water rights.

The impact statement understandably read more like a preliminary draft than a final report, because of the lack of time and precise information for its preparation. Possible physical impacts were discussed only in general terms, and social impacts did not receive much attention. The department thought that the public would be most concerned about the effect of warm water on the Waikato River — the station would need copious amounts of cooling water — and atmospheric pollution, and made a serious attempt to allay these fears, particularly the former. Some members of the local branch of the Institution of Engineers were concerned in particular about the disposal of grit collected in the proposed electrostatic precipitators, and the physical appearance of the power station. The cultural significance of the station's near neighbour, the Waahi Marae, was recognised in principle, but preliminary discussions did not identify any Maori concerns other than the proposed move of the Rakaumanga School.

Apart from farmers who would lose land, it was the local Maori who would be most affected. The Waahi Marae, which was adjacent to the power station site, was of national significance because of its association with Kingitanga (the King Movement). It was the principal marae of Ngati Mahuta of Waikato and home of the kahui ariki, the paramount family of Kingitanga. The Maori Queen, Dame Te Atairangikaahu, lived there, and her farm on the other side of the power station would be occupied during the construction period. Rakaumanga School would become less rural and lose some of its Maori character if it was moved. Some Maori families would have to move into Huntly West, and Te Kauri Marae would be affected. There were concerns about continued access to the river and the impact of flood-control works. The latter were, strictly speaking, independent of the station, one reason for their existence being the additional flow in the river as a result of the Tongariro scheme. There were concerns, too, about the general impact of the project on the ideals and community of the marae. While local Maori did not welcome the power station with the enthusiasm of the Huntly business community, they were not fundamentally opposed if the project contributed substantially to the development of the marae in a way that had long been beyond their resources.

A clause in the Electricity Act 1968 allowed the Minister the discretion to authorise the expenditure of up to 1 per cent of the estimated cost of a project for public 'amenities', which should be identified with the station and enhance its environment — making hydro-electric lakes attractive and available for public use, for instance. Requests for money had to be channelled through statutory or local bodies.

The Waahi Marae Committee wanted the level of the marae grounds raised in preference to the erection of a stopbank, so that access to the river would be maintained, and requested that the marae be substantially rebuilt, with new housing and community facilities. The committee also asked for the development of land between the marae and the river as a sports and recreation area. The department at first opposed these requests on the grounds that flooding of the marae would not result from power-project work, and that in any event the marae was not a 'public place'. Cabinet eventually decided that the marae would be regarded as a special case because of the effect the station would have on the 'rural nature' of the Waahi community. After negotiations most of what had been asked for was granted. In 1977 the Tainui Trust Board and the Waahi Marae Committee were both recognised as statutory bodies and therefore became eligible for grants.

It was accepted that, unlike previous projects with their purpose-built construction towns, the station would have a substantial and permanent impact on the town of Huntly, which would involve the department in considerable expenditure in addition to that provided for by the 1 per cent clause. In December 1973 a planning forum chaired by the District Commissioner of Works and including representatives of local authorities and government departments was established to deal with planning issues, and in February 1974 a liaison committee was formed.

The policy was that workers involved in the station's construction and operation would live in Huntly, which would increase the town's population considerably. Some contributions were clear-cut: a house for another doctor, and assistance for the ambulance and fire services, and for social services such as kindergartens and playcentres. The work-force reached a peak of nearly 2,300 in late 1978, but, thanks to the introduction of a travel allowance, nearly two-thirds of them travelled to the site from outside Huntly each day, so that the town was less affected than had been expected. Huntly's population had been 5,310 in 1971; by 1981 it was 6,452, an increase of only 21.5 per cent.

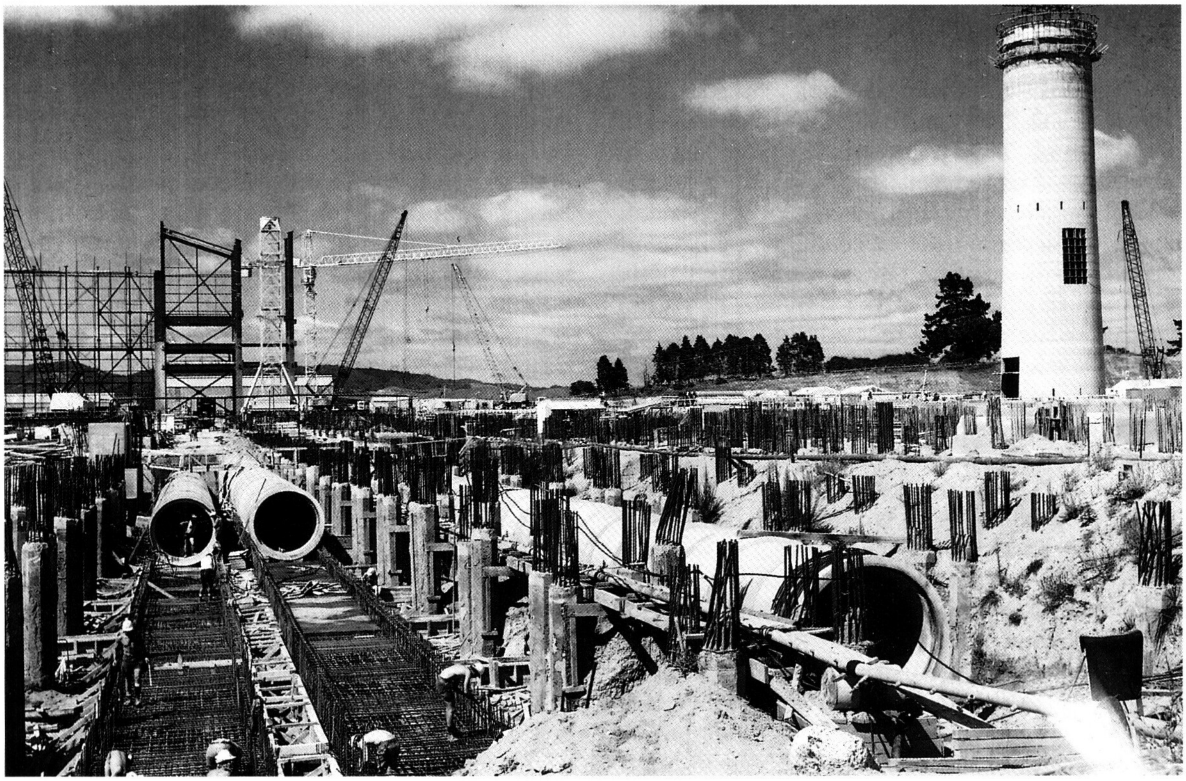
There was some controversy over the issue of grants for sports facilities. The borough council supported the Lower Waikato rugby union's proposal for a multi-purpose sports complex, but the department was not sure whether this was an appropriate use of the money. The Minister approved the idea in principle, but the project ran into heavy local opposition because Huntly was a league rather than a union town. The borough council then decided to consider amenities that would be used by the whole community, and received money for a long list of works. The rugby union proposal was saved when the Raglan County Council agreed to take responsibility for the complex, even though it would be built within the borough. In the end $1 million went to the borough council for a variety of projects, $750,000 to the local Maori community for the development of Waahi, Te Kauri and Kaitimu Marae, and $590,000 to Raglan County for the sports complex.

Huntly was the first thermal project for which the Electricity Department and the Ministry of Works and Development largely had responsibility for design and construction, and for which the bulk of the work was under Electricity Department control. In the past the department had been a junior partner to the ministry in hydro-electric construction, and at Meremere and Marsden an adjunct to the consultants. (A senior engineer from Preece, Cardew and Rider was seconded to the department to act as design-team leader for the station.)

The Huntly project was plagued by delays. The station had from the beginning been planned on a very tight schedule, and site conditions could not be investigated thoroughly in advance. There were delays in acquiring land, and much time was spent meeting clean-air standards. Different interpretations of seismic codes in North America and New Zealand led to further delays, and the boiler contractor had much difficulty in designing steelwork to meet New Zealand requirements. There were also delays in electrical and civil design and shortages of structural steel, while the erection of the boilers was seriously disrupted by industrial problems. As ever, skilled labour was difficult to attract.

Work started in October 1973. By August 1974 there were some 300 workers on site, and in September the first concrete pour for the powerhouse foundations took place. By early 1975 earthworks were largely complete and nearly half

Foundations for the Huntly thermal station. Some 2,000 piles had to be used because of the difficult foundation conditions. Condenser pipes to bring cooling water from the Waikato River are being laid at left.



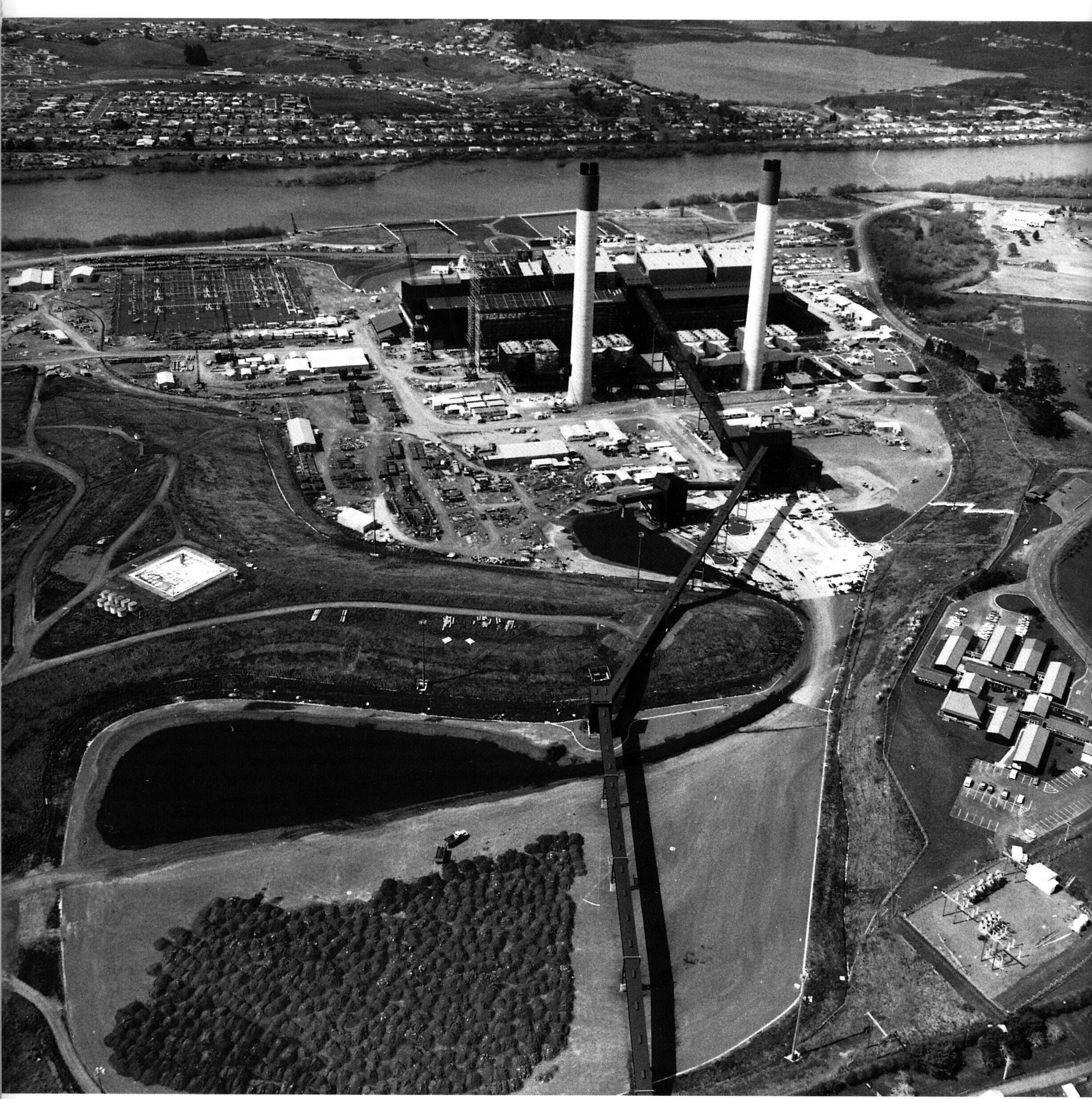
A view of the Huntly site with the two 150-metre-high chimneys approaching completion and the steelwork for the turbine house finished.

of the 2,000 piles for foundations had been driven despite difficult conditions. The contract for the two massive 150-metre-high chimneys was let, and work started on them in 1975. More than 500 houses were built and a single men's camp was established. At this time the Huntly Monitoring Project was set up at the University of Waikato to monitor and assess the economic and social impacts of the project.

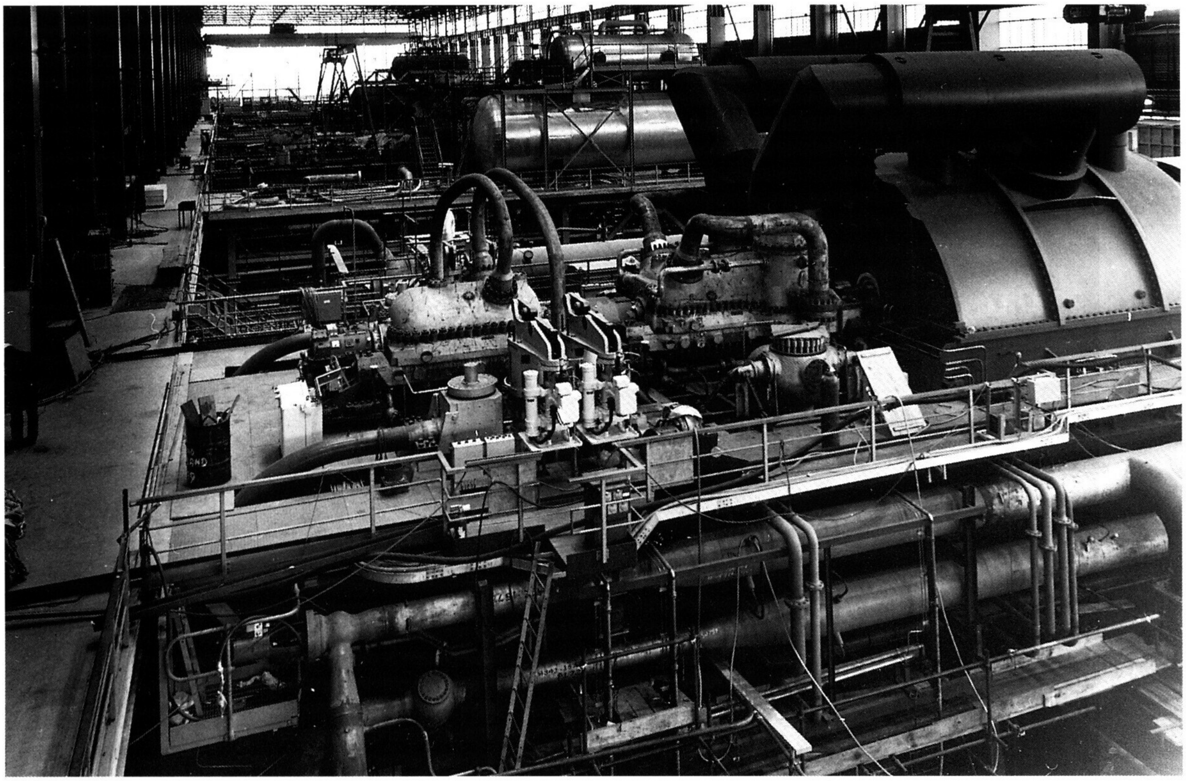
Late in 1975, when there were about 700 workers on site, the government restricted expenditure because of lower projections of demand for electricity, and work slowed down. No labour was recruited between September 1975 and April 1976. By now the piling was nearly complete and the foundations and cooling-water system were progressing well. Erection of the steel for the turbine house had begun, and the first chimney windshield was halfway up. In early 1977 the first windshield had been completed and the second was half finished, as was the turbine house. Work had begun on the coal-handling facilities.

The year of 1977 was the peak period of civil-engineering work. By 1978 plant was being erected and installed and civil works were almost finished. The very large 16,000-tonne concrete structure for the cooling-water intake and pump-house, constructed as a caisson on the edge of the river, was sunk into position by pumping sand out from underneath it. The steelwork for the turbine house, the cooling-water system, the control building, chimneys and coal-handling facilities had now been completed. The first generator was installed in early 1978, by which time the control building and turbine hall were virtually finished. The work-force began to be cut back by late 1978 as civil work came to an end.

Industrial conflict during the installation phase caused major delays, particularly with boiler erection. Shortages of design and operating staff and technical problems with the plant also slowed progress. The Ministry of Works and Development work-force used for much of the civil engineering at Huntly had a much better industrial relations record than those employed by private contractors, largely because the ministry



An aerial view of the completed station, showing the conveyor belt for delivering coal from Huntly West mine at centre bottom, the Waikato River used for cooling behind the station, and part of the town of Huntly across the river. The four 250 MW units were commissioned in the period 1981–85.



One of the massive 250 MW turbo-alternators is in the foreground of this view of the almost-completed Huntly turbine house.

worked with the New Zealand Workers' Union. The Workers' Union embraced well over 100 trades, which tended to prevent demarcation or other inter-union disputes, and its leadership was oriented towards keeping agreements and getting on with the job. By contrast, private contractors usually had to deal with as many unions as there were trades, and while composite site agreements were negotiated, they were very difficult to administer or enforce.

The first turbine was ready for steam by early 1981, but boiler erection was delayed. In 1981 and 1982 there were times when very little work was being done on the boilers. There were stop-work meetings or strikes on 44 of the first 70 working days in 1982. The boilermakers paid so little heed to site agreements or to procedures recommended by their own leaders that the contractor involved came close to declaring the site unmanageable. In June 1982, however, the contractor offered a 'completion incentive scheme' that was lucrative enough for work to continue.

The first unit was connected to the national grid in December 1981, and a milestone was reached when in May 1982 it produced its full 250 MW for a short time. However, it was still not functioning properly and did not generate power commercially until the following year. The station was officially opened by the Prime Minister, Robert Muldoon, on 9 April 1983, some five years after its original designated completion date. Commissioning of the first unit continued until September 1983. The second unit produced power in February 1983, the third was commissioned in March 1984 and the fourth in 1985.

While Huntly was originally intended to be a coal-fired station, gas had also been considered for one or two units. As gas became more important for petrochemical production in the early 1980s, it was decided to run Huntly entirely on coal, but by 1984 it had become clear that the only way to supply the coal in sufficient quantities was by 'longwall mining', a method which had not previously been used in New Zealand. Investigations showed that the seams of coal were fractured and displaced, which would make the use of this technique difficult.

Gas has become the main fuel for the station, and the shift to a more commercial approach has reinforced its continued use, by placing greater emphasis on using the cheapest and most readily available source of energy.

CHAPTER THIRTEEN

Geothermal Generation

NEW ZEALAND has a number of geothermal fields, most associated with the Taupo volcanic zone which runs north-east from the central North Island to the Bay of Plenty. In these fields the intense heat beneath the earth's surface 'superheats' underground water under pressure in reservoirs found in areas of fractured, fissured and permeable rock. The water does not boil and become steam until the pressure is released. The task is to extract the water or steam from the reservoir and deliver it as steam to a turbine.

Interest in exploiting this source of energy arose after the Second World War, when it was becoming apparent that sources other than hydro-electricity might have to be looked at to satisfy the North Island's demand for power. Semple stated in 1947 that the use of geothermal steam should not be overlooked and endorsed immediate investigations.[1] New Zealand soon became an international leader in the exploitation of geothermal resources.

Wairakei

The power station at Wairakei, just north of Taupo, was the second large-scale geothermal generating station in the world and the first to use 'water-dominated' or 'wet' steam.[2] 'Wet' steam, which is characteristic of New Zealand fields, is produced when the temperature gradient in the field is insufficient to convert all the water into 'dry' steam.

Geothermal energy was first exploited at Larderello in northern Italy around 1897. At first it was impossible to use the natural steam directly because it was too corrosive of the metals then used in turbines; instead it was used simply as a source of heat to raise steam in a boiler. By 1913 a 250 kW steam-turbine-driven generator using this method was supplying power to the ancient city of Volterra. These developments were familiar to engineers and others in New Zealand. In February 1918 the Masterton Chamber of Commerce asked for an enquiry to see whether the same technique could be used here. Nothing seems to have come of this, but others kept asking the same question. In 1920 an Auckland entrepreneur asked the government for the right to generate electric power by geothermal means near Waiotapu. Birks reported that generation would be feasible, but on too small a scale in comparison with hydro-electric power to be of any commercial use. In 1924 Dr E. Marsden tried to interest Furkert in the idea after the journal *Nature* published an article on the use of steam in Italy. Furkert's reply was much the same as Birks' had been — geothermal power would only be of interest if it was essential to use steam, and in New Zealand it was not. Furkert visited Larderello in the late 1920s but saw nothing to make him change his mind.

By the 1930s some scientists had become interested in the chemistry of geothermal water, and a large number of shallow bores were drilled at Rotorua, Taupo, Tokaanu and Helensville for heating and bathing. However, few here seem to have followed developments at Larderello in the late 1930s, when turbines that showed promising resistance to corrosion were built. By 1943 a 70 MW station had been commissioned there, but it was later destroyed by the retreating German army. A Public Works Department engineer who served in Italy was able to bring back a great deal of information about what had been done there.

Geothermal power began to emerge as a more realistic possibility during the period of post-war

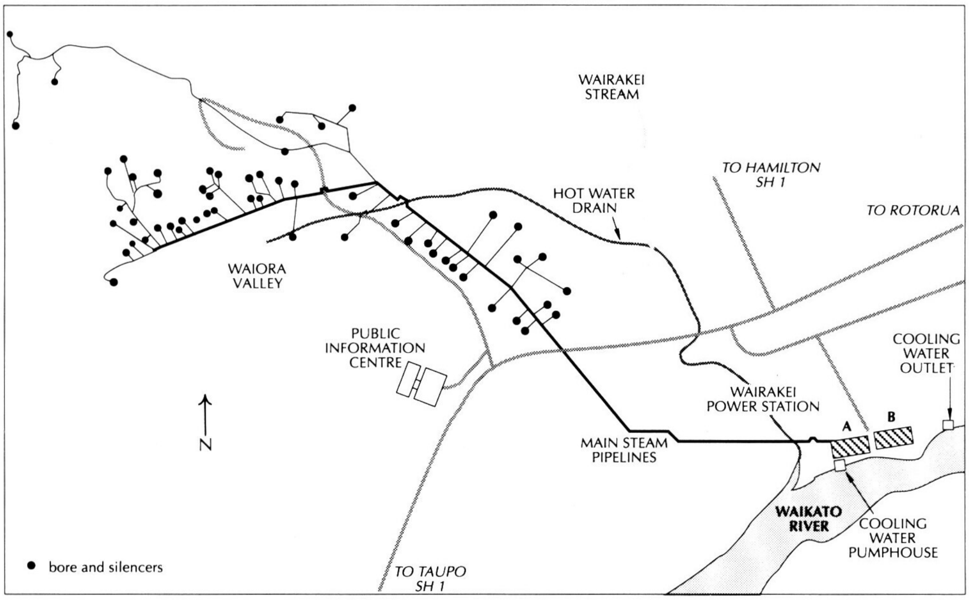
Wairakei Power Station

Constructed 1956–63. A geothermal plant using 'water-dominated' steam.

Stage 1: With a capacity of 69 MW, it comprised two 6.5 MW high-pressure units, two intermediate-pressure machines of 11.2 MW and three 11.2 MW low-pressure units. All the machines are in Station A.

Stage 1A: One further 11.2 MW low-pressure unit associated with the pilot hot water plant was added.

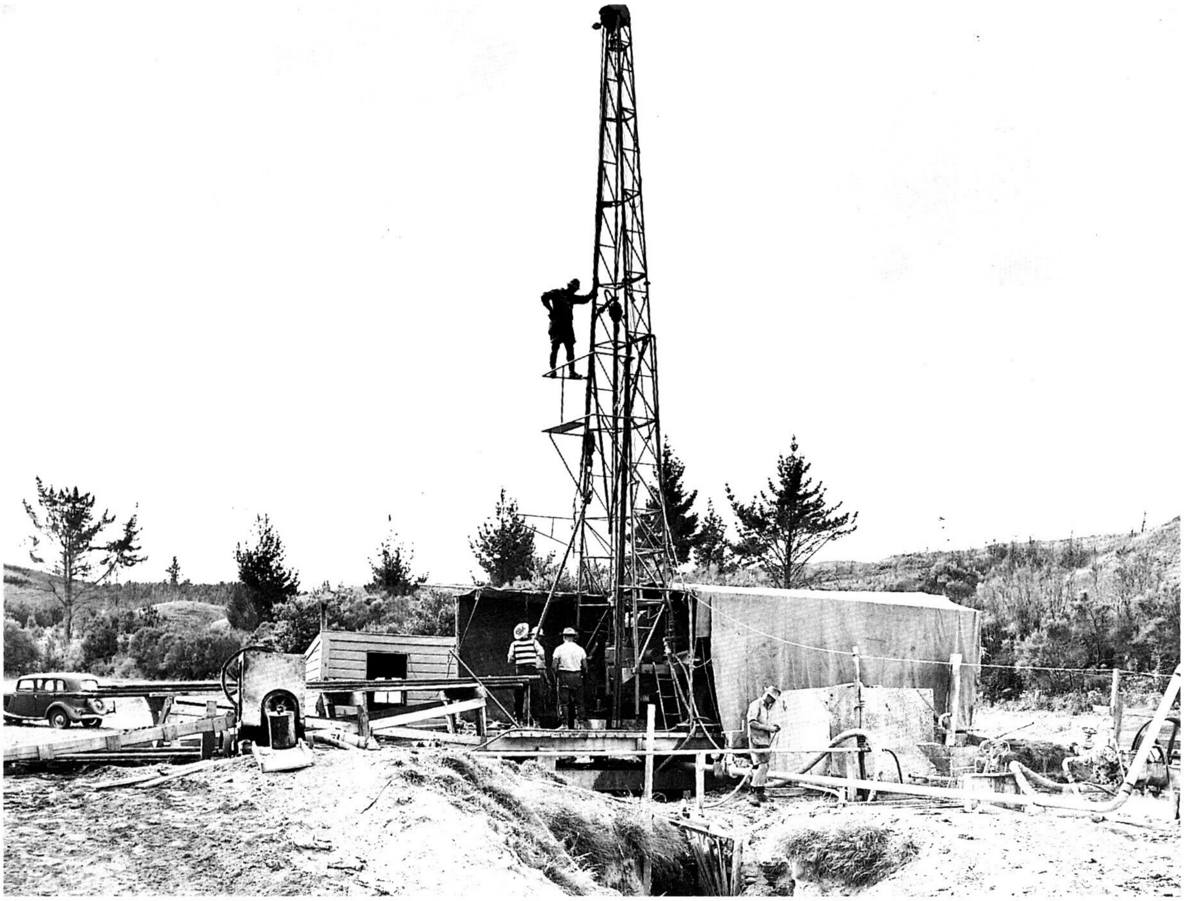
Stage 2: Two more high-pressure 11.2 MW units were included in Station A, and three 30 MW mixed-pressure units in Station B. This brought the total installed capacity to 190.6 MW. The high-pressure turbines were taken out of commission in the early 1980s because of falling steamfield pressures, reducing installed capacity to 157.2 MW. The addition of 18 MW from the Te Mihi development in 1988 has restored the station's output to close to its capacity.



shortages. The Rotorua Borough Council even asked for the Italian plant as its share of war reparations. When told that this was impossible, and that the State Hydro-electric Department had no immediate intention of developing the resource, Rotorua wanted to go it alone. Kissel, afraid that a makeshift drilling programme might be undertaken, argued that any geothermal power development should be by the state and in the long-term interests of the system as a whole.

By 1947 interest had quickened after two years of serious drought. In June Kissel recommended that investigations be made and trial bores sunk. Meanwhile local authorities kept raising the issue. In 1948 the Bay of Islands Electric Power Board wanted to exploit the Ngawha geothermal field and Taupo sought a geothermal plant. As a result of this pressure the Commissioner of Works and engineers visited Larderello to study the techniques used in deep drilling and the construction of bores. A Geothermal Advisory Committee set up in 1949 proposed a five-year survey of the whole thermal area from National Park to the Bay of Plenty, but the incessant clamour for development led to the committee recommending in November 1949 urgent investigation of the most promising area, Wairakei.

Drilling began in March 1950 using light rigs that were able to reach depths of 750 to 1,500 feet, and a camp for 50 men was set up at Taupo. Before long it was realised that they were dealing with something fundamentally different from Larderello. They were tapping superheated water that flashed 'wet' steam when pressure was released rather than 'dry' steam. Vigorous investigations continued. By April 1951 the Ministry of Works was fairly sure that power could be produced at Wairakei and anticipated that, as in Italy,

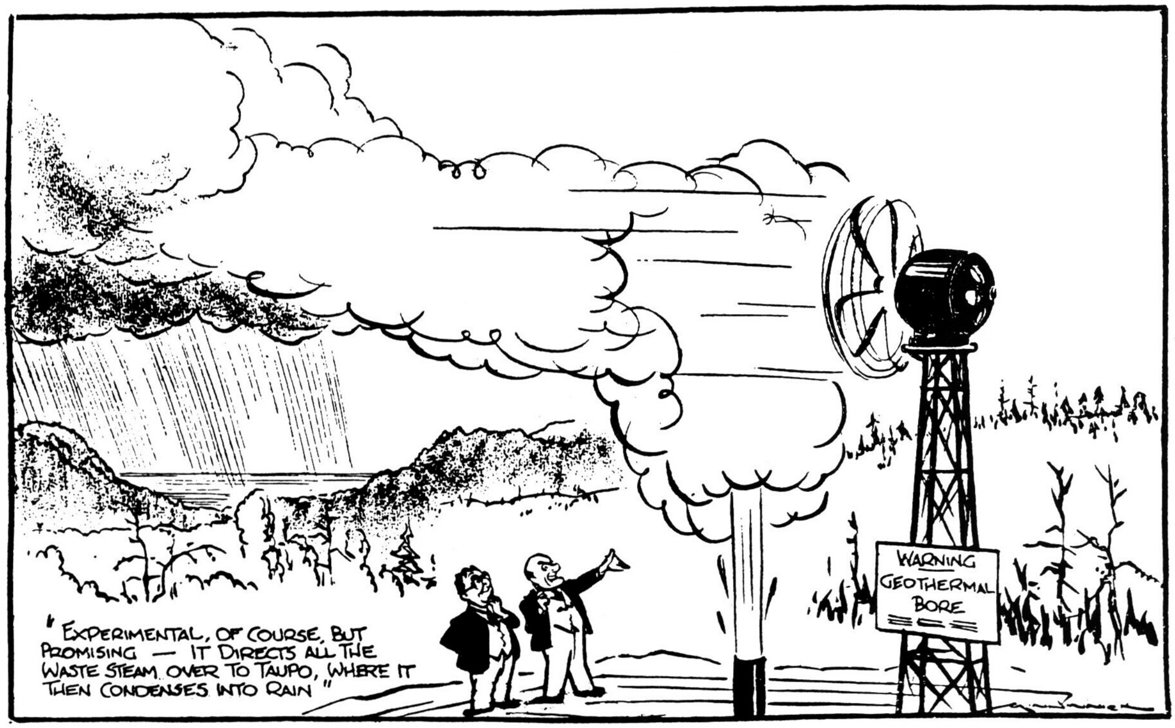


Above: An early drilling rig in the Wairakei geothermal field, March 1952. These rigs could not drill deep enough to prove the field, so larger T12 rigs were brought in later that year to drill several thousand feet down.

National Publicity Studios collection, Alexander Turnbull Library

Below: That some were sceptical of or poked fun at the notion of generating electricity from geothermal steam is indicated by this cartoon, which suggests an ingenious 'recycling' solution to energy shortages.

Gordon Minhinnick, *NZ Herald*, 1 May 1952


WARNING GEOTHERMAL BORE
"EXPERIMENTAL, OF COURSE, BUT PROMISING — IT DIRECTS ALL THE WASTE STEAM OVER TO TAUPO, WHERE IT THEN CONDENSES INTO RAIN"

GEOTHERMAL—STEAM—HYDRO—ELECTRIC

Sometimes Wairakei bores blew, as shown in this graphic shot. One such rogue bore was a considerable tourist attraction for a number of years until it was sealed.

DSIR, Science Information Division

deeper drilling would find dry steam at high pressure. Two development wells and fourteen prospecting wells had now been drilled.

Cabinet approved requests for new drilling equipment and to send three officers to Italy for first-hand study of the drilling techniques used for handling steam at high heat and pressure. This experience was of considerable value, but drilling conditions in the two countries proved to be very different. New and larger T12 rigs arrived in late 1952; they were able to go down to 3,000–4,000 feet and soon proved the potential of the field, finding superheated water at up to 480°C under pressure.

At this time there was a new twist to the story. Early in 1952 the United Kingdom Atomic Energy Authority at Harwell began to consider the development of a plant to produce 'heavy water' to be used as a 'moderator' in nuclear reactors. Sir John Cockcroft, the Director of Harwell, visited New Zealand on a lecture tour that year and told the government that momentous defence issues were at stake. Britain was to have its own nuclear weapons, and the real object of the exercise was the production of plutonium rather than electricity. The attraction of the geothermal resource was that nature had provided vast quantities of the hot water needed to produce heavy water.

After initial discussions about other geothermal areas Harwell advised in January 1953 that it seemed possible to combine a heavy-water plant and an electricity-generating plant at Wairakei, given that the former on its own would waste more than half the available steam. But the extent of the resource was still an unknown quantity. In April 1953 Davenport was on the point of recommending a 20 MW station, but a combined plant would need more than twice as much steam as had yet been proved.

In May 1953 Cabinet approved the combined plant in principle, and in August the consultants Merz and McLellan were engaged to report on its feasibility and cost. The government, which wanted to start building the station straight away, awaited the report anxiously. In early 1954 the British asked for six to twelve tons of heavy water a year from 1957. After receiving the report the Prime Minister announced that the plant would generate 47 MW (from two 6.5 MW high-pressure units and three 11.2 MW low-pressure units, with the heavy-water plant interposed between them) and produce six tons of heavy water a year as a joint venture. In February 1955 Geothermal Developments Ltd was formed, with the New Zealand Government and the British Atomic Energy Authority as its shareholders. Wairakei would produce power as a base-load station at the end of 1958. The State Hydro-electric Department would buy power from the company, and when there was no longer any need for heavy water the plant would revert to New Zealand control.

However, it was by now becoming doubtful whether heavy water had much future as a moderator, and indeed whether moderators would be required in the next generation of reactors. In January 1956 the British partner withdrew because of a relative shift in the economics of graphite- and heavy-water-moderated reactors, combined with a doubling of the cost of the heavy-water part of the plant. Wairakei became a New Zealand geothermal power project. It was too late for any radical redesign work, since the contracts for the turbo-generators had been let in 1955 and fabrication was well advanced.

The basic procedure developed for exploiting the field was to drill holes down to the reservoir to depths of up to 4,000 feet. The bores were allowed to vent into the air for some time to discharge debris. The holes were then cased with a steel tube, the lower part of which was slotted or perforated to allow the water to enter the pipe. The surrounding ground was extensively grouted with concrete to stabilise it, and valves at the wellhead controlled the flow. The discharge from the bores goes into cyclone separators that extract the hot water (which is more than three-quarters of the total discharge). The discharge enters the separator at an angle at high speed, creating a centrifugal action and allowing the water to drop to the bottom and the 'dry' steam to be collected by a vertical pipe near the top. Waste hot water is led to two adjacent 'silencing' towers, where its flow is split into two contra-rotating flows. The waste steam goes out the top and water out the bottom and into the Waikato River via the Wairakei Stream. It is this waste steam issuing out of the silencers that is the chief visual feature of the field.

The dry steam used for generation travels at speeds of up to 130 miles per hour along many miles of branch pipeline of six to twelve inches in diameter to more than twelve miles of main 20- to 30-inch pipelines and thence to the power station itself. In 1972 a 42-inch low-pressure pipeline was also installed. At intervals along the pipelines raised loops take up heat expansion and steam traps deal with condensation and droplets still suspended in the steam. The steam then enters the powerhouse and, depending on its pressure, drives the appropriate turbines. High-pressure steam joins the intermediate-pressure steam after going through the high-pressure turbines, and intermediate-pressure steam, after use, likewise joins the low-pressure steam supplying the low-pressure turbines.

The two Wairakei stations (A and B) were sited by the Waikato River for ease of access to cooling water. They were built on raft foundations because of the ground conditions. Large quantities of water are required to condense the steam leaving the low-pressure turbines. Condensation increases the pressure differential and allows the generation of twice the power achievable without it.

An additional two intermediate-pressure machines of 11.2 MW replaced the heavy-water plant, and the planned capacity of the station was raised to 69 MW. Wairakei's machines were designed to operate variously on high (about 180 psi), intermediate (50 psi) and low (0.5 psi) steam pressure.

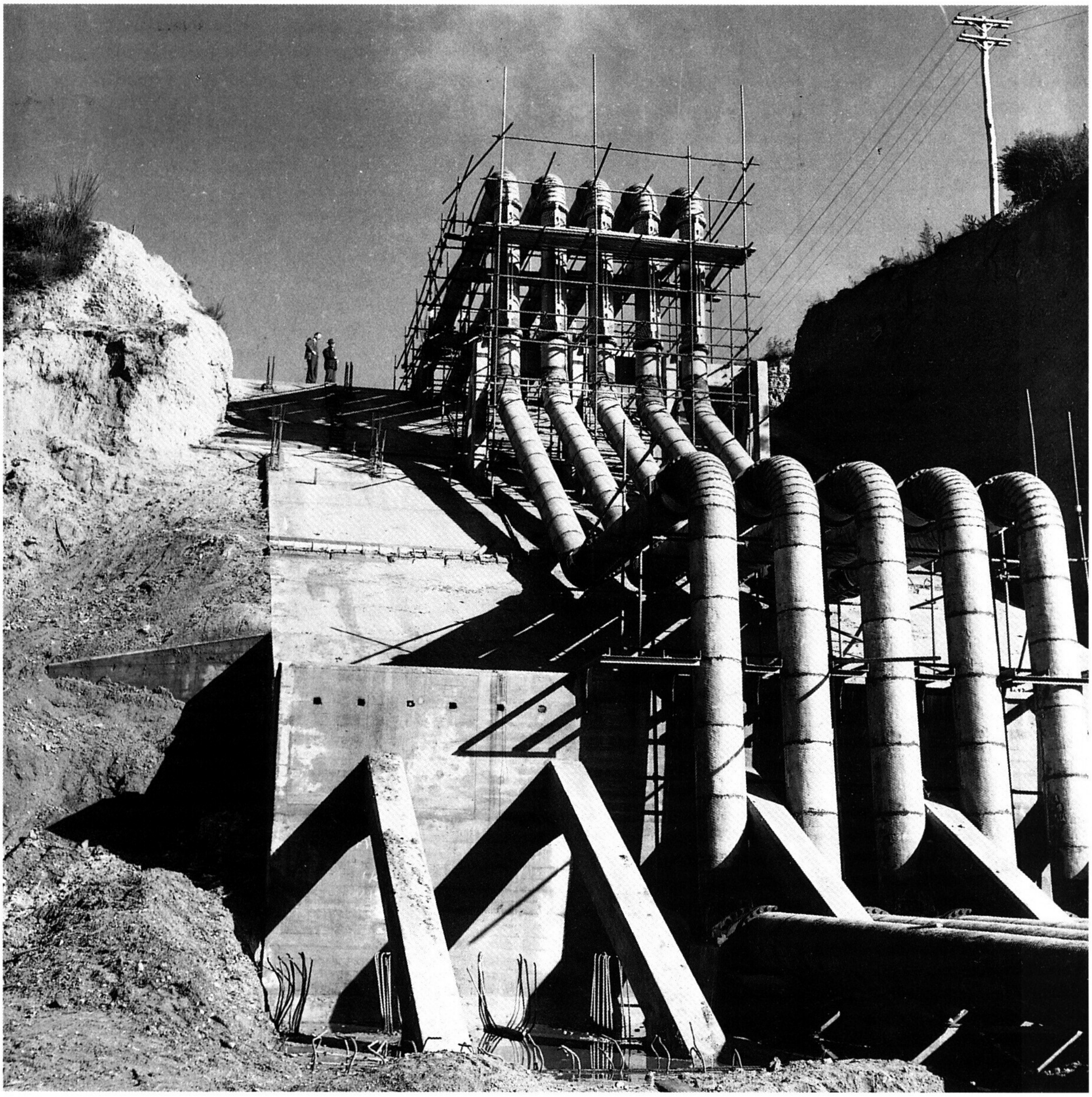
During 1956 construction of the station and development of the field proceeded rapidly. The major contract was let to International Contractors, a combination of New Zealand, British and Swiss firms. A camp for 100 men was set up on the site, and some 27 production bores were established. Work was done on powerhouse foundations, the cooling-water pumphouse and culverts, and on five 20-inch steam pipelines, which by 1958 extended eight miles up the valley; branch pipelines were also being built. Up to 700

Right: Getting steam to the Wairakei powerhouse required a maze of pipelines of varying sizes spanning many miles. This view taken in 1958 about one and a half miles from the station shows a twelve-inch-diameter branch pipeline crossing the main pipeline and feeding into another main carrying steam at intermediate pressure. The two high-pressure twenty-inch-diameter main pipelines are under construction with a raised expansion loop in the background. Near the loop is a bore with its accompanying twin silencing towers.

National Publicity Studios collection, Alexander Turnbull Library

Below: The main twenty-inch pipe corridor descending the escarpment near the Wairakei station, August 1958. Provision has been made for additional pipes.

National Publicity Studios collection, Alexander Turnbull Library



were employed on the project when work was at its peak.

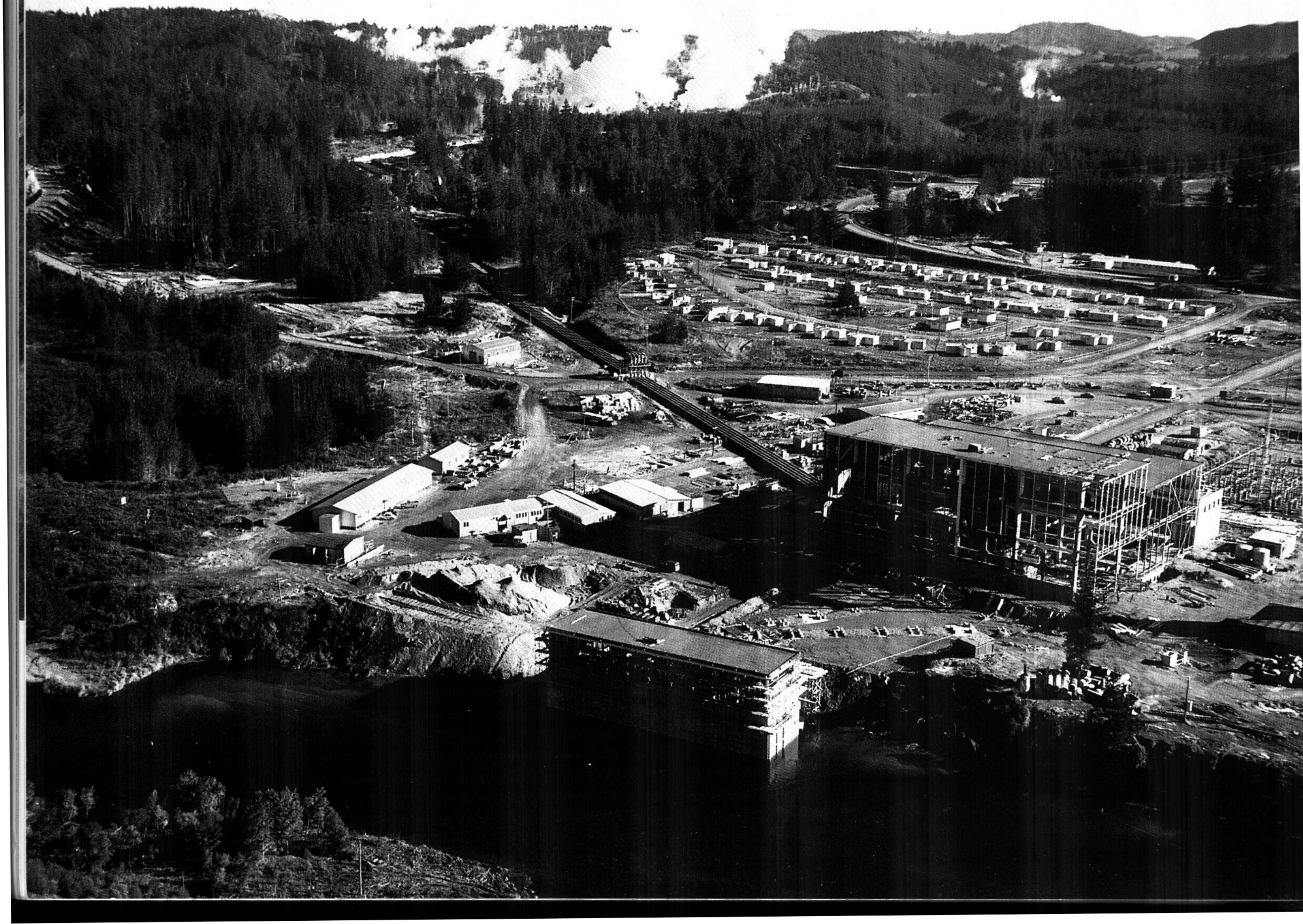
Because more steam was found in the field, a second stage of development was proposed and two more high-pressure 11.2 MW units were included in the station, and another adjacent station with three 30 MW mixed-pressure units (the turbines could run at either 50 or 0.5 psi) was planned. These were the largest geothermal steam turbines in the world. This brought the total planned capacity to 190.6 MW. It was hoped that another two 30 MW units could be added later as Stage 3; the design took this into account.

At this time the consultants Merz and McLellan advised that the project should proceed to Stages 2 and 3, subject to evidence of adequate geothermal resources, and could produce as much as 250 MW if the waste hot water could be converted into steam. Tenders for Stage 2 were called.

By 1958 drilling for Stage 2 had begun, and the pumphouse and powerhouse were nearly completed. The first unit was commissioned on 13 November 1958, but its operation remained limited because of the extensive testing required and early plant failures. By March 1960 all the Stage 1 units were producing power and the station was generating 50 MW at peak; this rose steadily as further units were brought into service. By 1962 the station was achieving the high load factor that was intended. In the last two months of that year Wairakei produced more energy than any other North Island station. From 1966 (apart from 1968 when the field was partially shut down) the load factor was a very high 85 to 90 per cent. The remaining units were commissioned at regular intervals, with the last 30 MW Stage 2 unit producing power in October 1963.

The two Wairakei stations were built on raft foundations beside the Waikato River for access to cooling water. The large cooling water pumphouse can be seen on the riverbank. This view of June 1958 shows the partially complete Station A. The steamfield pipelines enter the station from the upper left, and in the background steam billows from the field. Station B was to be built immediately to the right of Station A.

National Publicity Studios collection, Alexander Turnbull Library



It was hoped to use the hot water discharged in the field for producing further steam, and techniques for transmitting the hot water from the wellhead extraction pumps to the power station were developed. Water was collected from a group of wells and kept pressurised by pumps at the wellheads to prevent it flashing to steam before reaching the station. Such techniques were entirely untried for the volumes involved. A pilot hot-water 'flashplant' using hot water from seven bores was eventually incorporated into the station. This supplied intermediate- and low-pressure steam.

Even before Stage 2 was completed and the three 30 MW machines were commissioned in 1962–63, it was clear that the Wairakei reservoir was running down; pressures and steam production were falling off. The commissioning of Stage 2 accentuated this problem. The pilot hot-water flashplant scheme was eventually commissioned successfully in July 1963, but ran for less than a year before falling water output led to it being abandoned.

Production drilling continued until the mid-1960s, and the actual peak power output of 173 MW, still short of the installed capacity, was achieved in 1965. By then over 120 bores had been drilled, and the emphasis had shifted to managing the field to sustain existing capacity. Pressures for the high-pressure units were allowed to drift downward over the years, rather than a more rapid rundown at full pressure.

The idea of flashing the separated high-pressure bore water was not forgotten. It was applied again from the mid-1960s, first with double flash units installed at selected high-pressure wellheads, and then with the establishment of several semi-centralised double flash plants. These produce additional steam by allowing high-pressure hot water to flash to steam twice (producing intermediate pressure) or three times (low pressure). In November 1982 the process of derating the high-pressure bores to intermediate pressure began, as pressures had fallen to a level that could no longer sustain high-pressure generation. The station's capacity was reduced to 157.2 MW as the high-pressure turbines were decommissioned.

By September 1988 the Te Mihi development involving three wells was completed. By adding 18 MW, this restored the station's output to close to its capacity. The reinjection of waste hot water has been investigated since 1982, and in March 1991 work that will enable the reinjection of more than half of the total discharge was approved as a first stage.

Some 50 wells are currently in production, and the station produces about 153 MW net, but maintaining this output requires continued work. Although Wairakei has not produced the 250 MW that was initially hoped for in the late 1950s, its output is close to installed capacity. It has been a remarkably reliable performer and has the highest load factor of any station in the country.

Ohaaki

By 1964 it was accepted that Wairakei could not be extended, and increased expenditure was allocated to investigations for a second station.[3] In 1965 drilling started at Broadlands (as the project was then known), between Taupo and Rotorua. The name of the station was later to be changed to Ohaaki at the request of Ngati Tahu, the owners of the land on which it was built. After several years of drilling, however, there was little enthusiasm for further investigations. The Electricity Department in particular gave it a low priority, although the Ministry of Works was more enthusiastic.

A major reason for the lack of eagerness was the small size of the potential station. The view at that time was that only stations with an energy output of at least 2,000 GWh a year were worth bothering about. Transport and other constraints limited the turbo-alternators to a maximum capacity of 50 MW, which meant that a geothermal station large enough to be of interest would need more than half a dozen machines. In 1968, nonetheless, the Ministry of Works decided that Ohaaki was the most promising geothermal

Ohaaki: Constructed 1982–89. Some 25 production wells on either side of the Waikato River produce hot water. After passing through a separation plant (of which there are five) the waste hot water is reinjected into the ground by pumps. The steam is piped to two 11.2 MW high-pressure turbines, (refurbished units from Wairakei) and two 46.9 MW intermediate-pressure turbines, in separate buildings. The steam is condensed by circulating water that is cooled in a huge concrete natural-draught cooling tower, the first in New Zealand. This is 105 metres high, 70 metres in diameter at its base and 40 metres in diameter at the top. It takes out up to 420 MW of heat from the 20,000 tonnes of water that circulate every hour. Total capacity is about 108 MW.

possibility and that all efforts should be concentrated there, even though the field suggested that only 90 MW could be produced. The ministry argued that a station should be built as soon as possible in order to reduce imported fuel costs and to get a return on money already spent on investigations.

By 1968 the Electricity Department had become even less enthusiastic about the project, and in 1970, with the prospect of Maui gas, Ohaaki was relegated to form part of a backup plan. After an inter-departmental committee decided to stop investigations, drilling ceased in June 1971 and the wells were closed. The Ministry of Works considered that the 25 wells it had drilled had proved a potential for 100 MW (net), and thought that an eventual 180 MW (gross) would be feasible.

The Labour Party's 1972 election manifesto, written against a background of growing environmental concerns and an emphasis on indigenous energy sources, promised further development of geothermal resources, and after Labour's victory the project was revived. The Electricity Department now accepted that Ohaaki had to be taken seriously. From the point of view of the system as a whole it seemed more attractive than the Marsden B station, which was also under consideration. However, the disposal of geothermal waste water was a major issue, the technique of reinjection being by no means proven. It was most unlikely that the department would again be allowed to let waste water flow directly into the Waikato River.

In July 1973 the Ministry of Works and Development's drilling programme was reinstated and two years' further work was authorised. The drought years of 1973 and 1974 and the oil crisis both put more emphasis on alternative sources of energy and made a geothermal station more attractive to the Electricity Department as a base-load plant that could be built quickly. The 1974 power plan consequently included 50 MW from Ohaaki in 1981 and another 100 MW a year later.

There was a great deal to be done. While past experience was an immense help, it was not simply a matter of duplicating Wairakei. The process of reinjection had been used in Japan and the United States, but not to deal with such a large volume of water nor in the same conditions. The condensing water would have to be cooled to avoid introducing warm water into the Waikato River. The waters of the Waikato had been warmed for many years, partly because of Wairakei but also owing to the conversion of the river's flow into a series of hydro-electric lakes. The massive Huntly station was also to use river water for cooling. The Environmental Impact Report published in December 1977 made it clear that waste hot water going into the Waikato would substantially increase the problems posed by warm water and chemicals, and decrease water quality a long way downstream. The water rights granted prohibited discharge into the river. A backup cooling pond was included in the plans in case reinjection proved not to be possible.

In 1977 the commissioning date for Ohaaki was put back because of design work required and complex negotiations with the Maori owners over land usage. The following year a two-stage development with an initial capacity of 80 MW was proposed because of doubts about the yield of the field. Reinjection was adopted and the cooling pond was replaced by a cooling tower. The project was delayed further, as it was now seen more in terms of maintaining and developing geothermal technology than for its actual generation potential. The reduction in capacity would allow the use of the high-pressure turbines that were to be decommissioned at Wairakei.

While the field on the eastern side of the Waikato River was Crown land, that on the western side was Maori freehold and the ancestral area of the Ngati Tahu tribe. The power station site lay close to Te Ohaaki, their principal marae, a sacred rock, and the Ngawha Reserve, which contained a large hot pool and an urupa. The Maori land was divided into several blocks, each with multiple absentee owners numbering nearly 900 in total. The Taupo County Council had applied to the Maori Land Court to have the land vested in the Maori Trustee, who leased it to the Ministry of Works for twelve years to allow geothermal investigations. The owners had no control and little involvement over this period.

From 1976 the Ministry of Works and Development had considered buying the land, arguing that the Crown must have the freehold of land on which it put large capital works. It was proposed to exclude the marae, the sacred rock and Ngawha Reserve from purchase. Some officials thought that Maori links with land could survive its leasing but not its sale. Applications were made to the Maori Land Court for purchase and this required the calling of a meeting of owners by the Court. Compulsory purchase under the Public Works Act was considered.

After nearly a year had been spent in arranging it, a meeting with the owners presided over by the Chief Judge of the Maori Land Court took place in November 1978. There was nothing like a quorum present for any block. Those who did attend heard and questioned government officials and agreed to appoint trustees to represent them. The Ngati Tahu Tribal Trust was established in February 1980. The trustees had no powers to sell the land but could negotiate with the Crown a lease or an exchange of land. While the owners did not object to the building of a station, they would not sell the land and were unanimous in refusing to consider an exchange for land elsewhere. They wished to hold fast to their turangawaewae (home land). Most did not want the meeting house moved, even if the price of staying was considerable noise during the construction period.

Instead of proceeding unilaterally under the Public Works Act, it was decided that the Ohaaki project should be subject to the designation requirements of section 118 of the Town and Country Planning Act. A 'Ministerial Requirement' for designation of the land for electricity generation purposes was served on the Taupo and Rotorua County Councils (whose boundary was the Waikato River), and this was advertised for public objection in November 1978. Ngati Tahu sought assistance from sympathetic Waikato academics with experience of Huntly. Their concerns were heard and additional conditions and modified boundaries of the designated area were recommended to and accepted by the Minister of Works.

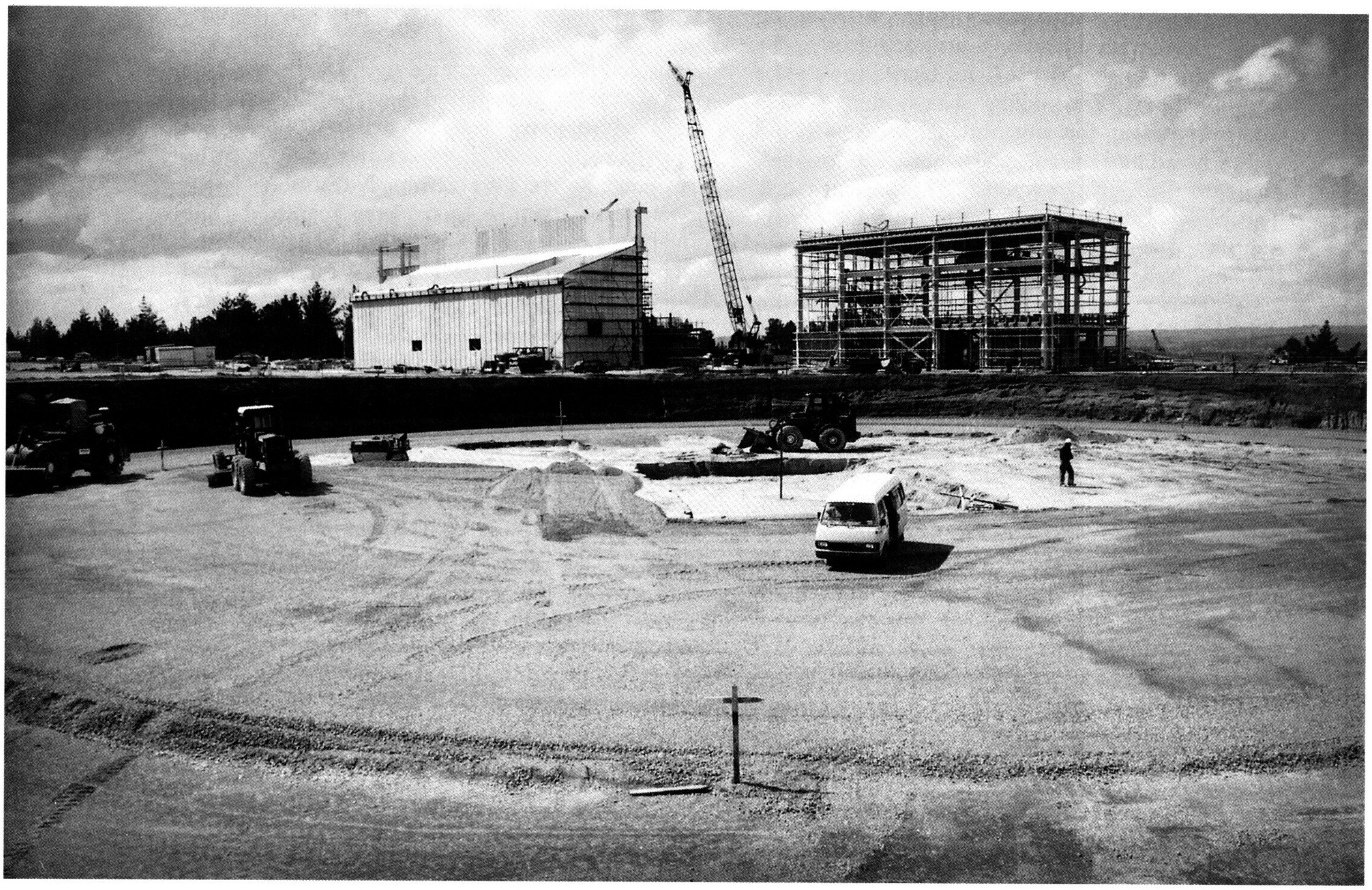
There remained the outstanding question of the tenure of the land. Ngati Tahu lodged an appeal with the Planning Tribunal, which in February 1980 declined jurisdiction, arguing that the issue of tenure was outside Town and Country Planning Act procedures. The question would have to be dealt with under either the Maori Affairs or the Public Works Act. The chairman of the tribunal remarked, however, that if the Public Works Act was used to take the land, objections to this could come before the tribunal. He added that while in theory the Minister could override the tribunal it was not likely that he would in practice. This was taken as a warning not to attempt to use the Public Works Act.

In any case political realism was beginning to assert itself. An attempt to acquire the land compulsorily would be likely to turn the problem into a major public issue. In the course of 1980 officials became anxious because the planning recommendations committing power for electricity-intensive industries implied rapid access to the station site. But they found they could do nothing to speed matters up. The trustees, while not opposed to the power station and anxious to be reasonable, were also extremely cautious lest a decision made in haste be later regretted. The government departments involved considered different solutions. The Ministry of Works and Development proposed that the Public Works Act should be invoked after all. This was opposed by Maori Affairs, while the Electricity Division suggested that a lease rather than compulsory purchase would be appropriate.

After the possibility of an exchange of land had been explored, this was rejected by the trustees. In May 1982 the question of compulsory acquisition was again raised in the Cabinet Works Committee, but it was pointed out that this would in all likelihood only lead to further delays. In July 1982 an agreement was signed for a 50-year lease to the Ministry of Works and Development, with two rights of renewal for a similar period but no right to assign or sublet. This was a major departure from previous practice. The Crown's usage was to be restricted to electricity generation. The agreement also protected the marae, urupa and other sacred places, and included restoration of the hot pool and a supply of steam and hot water to the marae as desired by the trustees. Ngati Tahu also received an amenity grant under the 1 per cent clause of the Electricity Act, with which they restored and upgraded the marae.

The agreement subsequently created problems when it was announced in 1986 that various government departments, the Electricity Division amongst them, were to become state-owned enterprises legally distinct from the Crown. It was essential for the Crown to be able to transfer the lease to the proposed Electricity Corporation. In June 1986 the trustees agreed in principle to work towards another suitable agreement, but this has not yet been formalised.

Early in October 1982 the Cabinet Works Committee was asked for approval to begin work on Ohaaki. It was argued that there was a need to retain design staff and take the next essential step in the development of geothermal resources. Ohaaki also had the advantage of having all the necessary statutory and environmental approvals. Approval was given that month, and major contracts for plant were let in November with a completion date of the end of 1988.

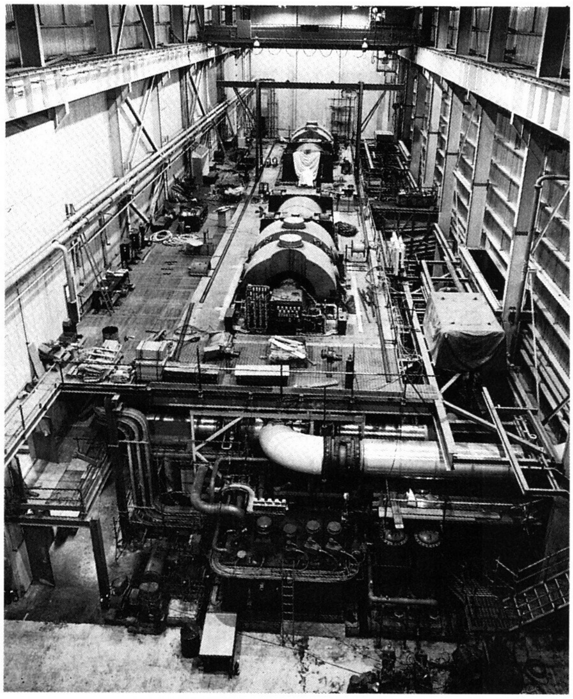


Excavating the circular foundations for the large concrete natural-draught cooling tower at Ohaaki. In the background the two turbine houses are being erected. A feature of the tower is its special 'ring beam' foundation giving protection against earthquakes. It was decided that the Waikato River should not be used for cooling purposes, so the first such tower in New Zealand was designed for this project.

Work on the site started at once. The scheme was designed with a large natural-draught cooling tower 105 metres high, the first such tower in New Zealand and a striking visual feature. The tower was designed with a special 'ring beam' foundation for earthquake protection. By early 1984 several production wells had been readied and construction of the plant was well under way, with powerhouse excavations complete and the contract for the cooling tower let. By early 1985 the earthworks and foundations for the main building were finished and steel erection was proceeding. A start had also been made on the excavation of the foundations for the cooling tower, which had been let to Wilkins and Davies MCE Joint Venture. A year later the project was nearly half finished, with the high-pressure turbine house almost complete, the main turbine house and cooling tower foundations finished and steamfield earthworks progressing well. By early 1987 Ohaaki was two-thirds complete, with the tower shell and turbine houses up. Work had reached its peak, with 600 on site. A year later the tower shell and the west steamfield pipework and separation plants had been finished, while the east steamfield works were half complete.

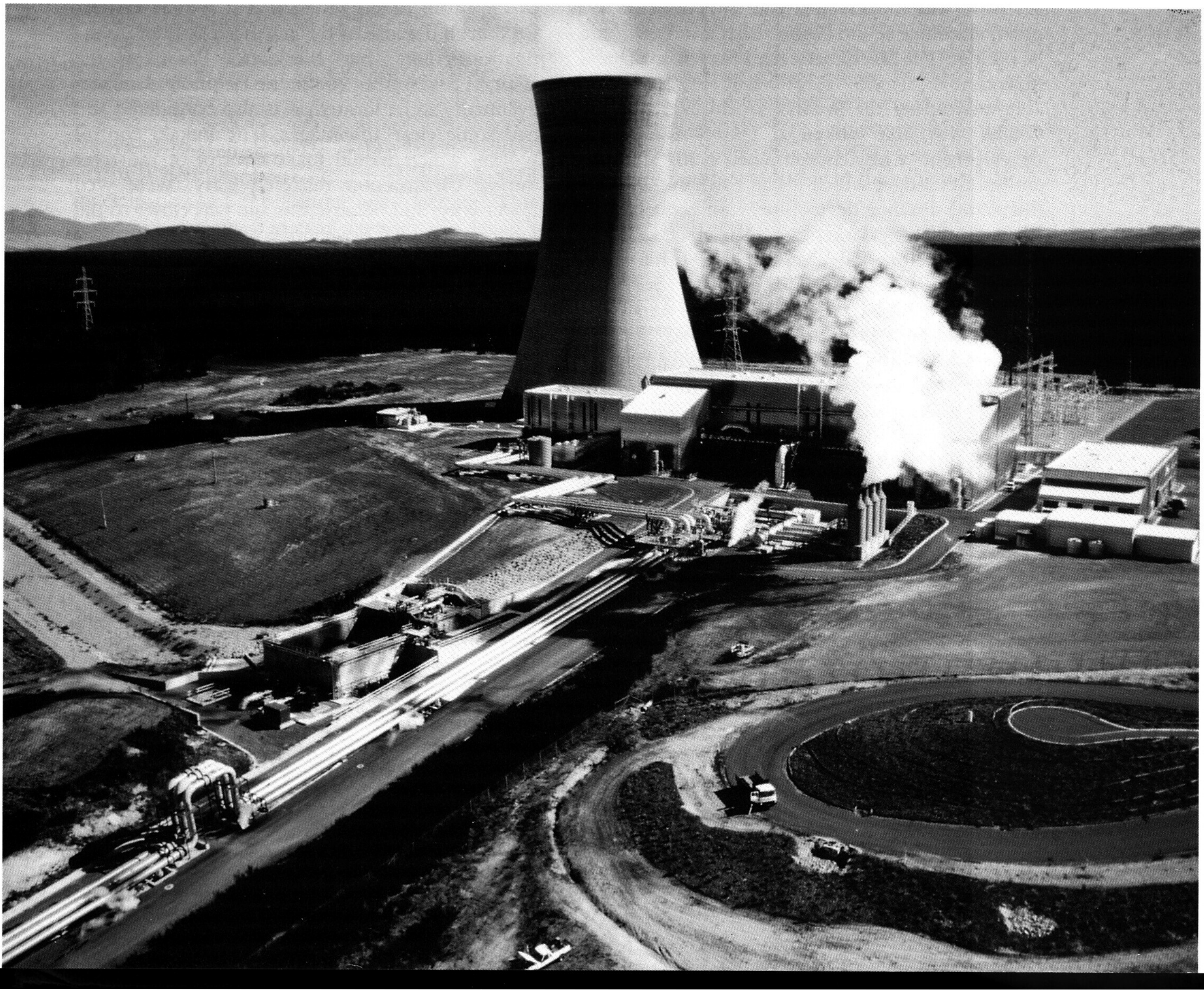
Ohaaki began generating power from two units in February 1989, was fully commissioned in July and officially opened in October in a joint ceremony involving Ngati Tahu. The station had been built within budget and on schedule.

High-pressure steam and water is extracted from the field of about 1,000 hectares and enters the first-stage separation plants. The steam then drives the high-pressure turbines before passing to the intermediate-pressure turbines. Water from the first-stage separation plants goes to the intermediate-pressure separation plants and is again flashed to steam to drive the intermediate turbines. There are also intermediate-pressure production wells delivering steam directly to the intermediate turbines through separation plants. The steam from the intermediate turbines is condensed by circulating water that is itself cooled in the natural-draught cooling tower. The high levels of non-condensible gases (largely carbon dioxide and hydrogen sulphide) are extracted from the condenser and exhausted via the cooling tower to avoid high concentrations at ground level. Reinjection pumping stations adjacent to the separation plants pump the water, which contains arsenic, boron and mercury, back into the field. The station is operated by remote control from the Wairakei Area Control Centre.[4]



Right: Inside the main intermediate-pressure turbine house at Ohaaki.

Below: The completed Ohaaki power station, with its large cooling tower, in April 1990.



CHAPTER FOURTEEN

The Clutha

HYDRO-ELECTRIC GENERATION on the Clutha River was not considered seriously in either Hancock's or Hay's report of 1904, even though it had the greatest flow of any New Zealand river, averaging 18,500 cusecs at Roxburgh. Hancock thought that dams would be too large, costly and difficult to build. In his opinion the flow was too variable and silt problems too great, although he did suggest that a station could be built at 'The Neck' between Lakes Wanaka and Hawea.

It was during the Second World War that the Clutha was first looked at closely for power development. Christchurch hated being dependent on Coleridge, which it had to share, and had demanded a major development on the Clarence River in North Canterbury. Kissel declared in 1943 that before any decision was made more information was needed about not only the Clarence but also the Rakaia, the Waitaki, the Clutha and Lake Hauroko in Southland. Surveys of the Clutha and Kawarau Rivers, from Roxburgh up to Lake Wakatipu, began in 1944.

There was a good deal of discussion at that time as to how much expansion of demand should be allowed for in the South Island. Unrestricted demand might see an initial annual growth rate of 10 per cent, but this was considered unlikely to persist in the long term. Even if the growth rate was only 5 per cent, it was likely that there would be severe shortages in 1952 and 1953 if they were dry years, and if it was 10 per cent there was no way that a new station could be built in time. Roxburgh was designated as the scheme that was to satisfy South Island demand for many years to come.

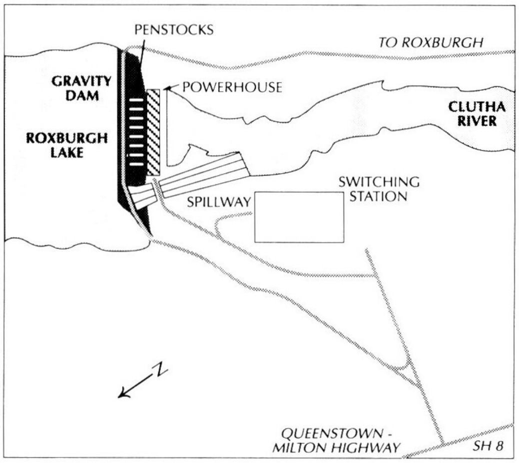
Roxburgh

Until Benmore, Roxburgh was by far New Zealand's largest hydro-electric scheme. It was built at a time of considerable scarcity of both materials and labour.[1]

The dilemma was where to put a new station. Sites were investigated from 1946. The urgency of the problem suggested that it should be near Roxburgh because of the advanced state of investigations there, but Blackjacks Point on the Waitaki River (near where the Benmore dam was eventually to be located) was also considered and had some clear advantages. The Pukaki control works, which would make control of the river during construction relatively easy, were well under way, and because this site was closer to the load centre of Christchurch, transmission costs and losses would be smaller. However, Blackjacks Point was physically remote, with no sizeable town nearby, and twice the amount of construction materials would be required — an important consideration in the post-war years of scarcity. Crucially, more than a year's further investigation would be required.

In August 1947 Kissel recommended Roxburgh, arguing that the only way out of the existing shortages was to build a station big enough to give a respite for a substantial time. The department's view was that all of New Zealand's major hydro-electric sources would have to be used. If another scheme eventually turned out to be cheaper than Roxburgh, the advantage would only have been deferred, not lost. The Manapouri scheme was the only other possible proposal of sufficient size, and had been briefly considered, but labour would have been much harder to attract, with no prospect that the many skilled tunnellers required could be found. Cabinet

Roxburgh: Constructed 1949–56. Head 150 feet. A concrete gravity dam 1,200 feet long and 250 feet high. The diversion channel is 1,800 feet long and incorporated into the spillway. There are three large spillways with steel gates, 45 feet high and 54 feet wide, each weighing 135 tons. Eight welded-steel penstocks 18 feet in diameter lead the water to 40 MW turbines. At first only four units were installed, the additional four being installed in 1961–62. Total capacity is 320 MW.



approved Roxburgh in December 1947.

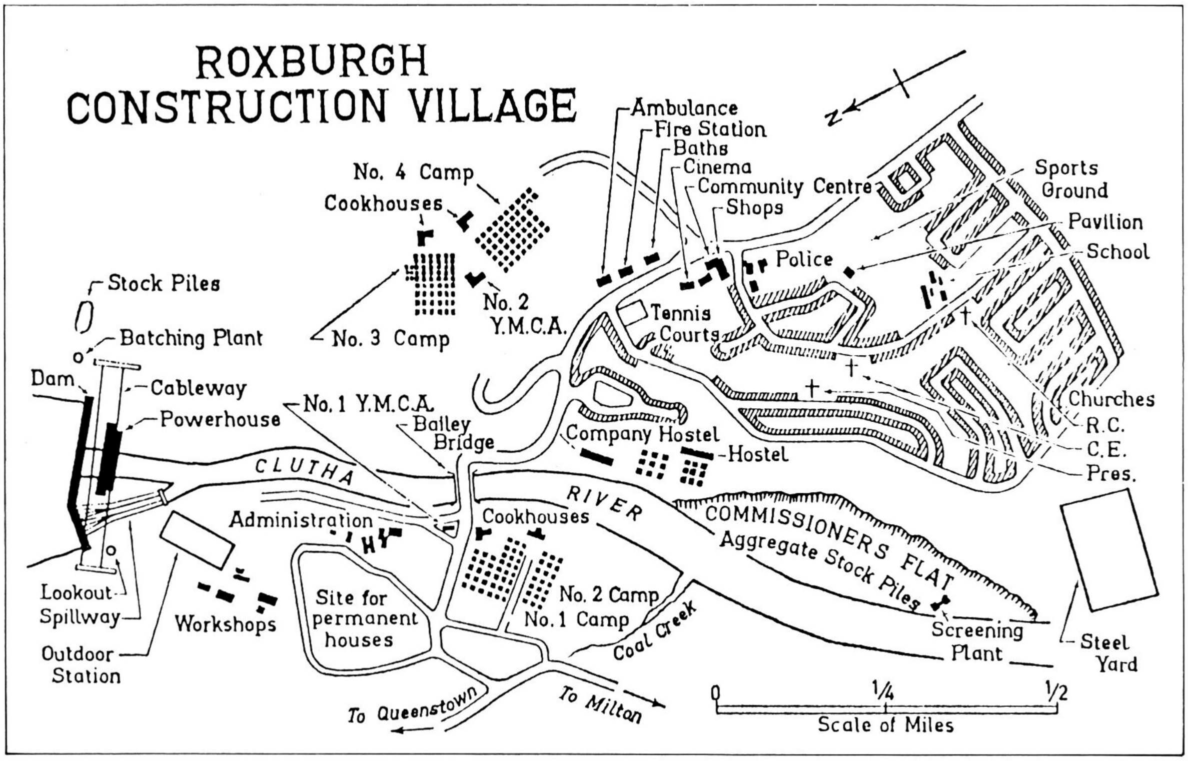
It was now discovered that basic hydrological investigations of the Clutha were lacking. This had to be remedied in tandem with the detailed engineering investigations, which narrowed the number of possible sites from six to four and then to two in the Roxburgh Gorge. One site seemed to offer greater ease and speed of construction, and was suitable for a dam of earth and rockfill — a very important consideration when cement was in short supply. The alternative site downriver at Tamblyn's orchard, some five and a half miles upstream from Roxburgh and on the last bluff of the gorge, was suitable only for a concrete gravity dam but had the advantage of a higher head and better tailrace conditions, as well as being closer to Roxburgh itself. The latter site was chosen in March 1949.

Debate as to the height of the head and the control of the lakes upstream now took place. Since the highest flows in the river came in summer, lake controls were crucial to store water for winter. The head would have to be fixed low enough to ensure that Alexandra and Clyde would not be affected, even by the maximum anticipated 'design' flood. A higher head, which would allow an extra 40 MW to be generated but involve a delay of several months, would require a control system for all three lakes to deal with severe floods.

Semple's first response was that such a small gain paled in comparison with the consequences of holding up the development of the country. But his real objection, prised out by Davenport, was that he did not want the department to be responsible for operating a flood-control system that would have serious wider implications. The original proposals included the 'complete' development of control for the lakes. In December 1947 Semple stated that this would mean varying the level of Lake Wanaka by about fifteen feet and Lake Hawea by about 60 feet. Without substantial storage the project could not be justified, since the river's uncontrolled flow would not allow even three of the proposed eight machines to operate continuously.

Control gates had been installed at the outlet of Lake Wakatipu in the 1920s in an attempt to get at gold supposed to lie in the Kawarau riverbed, but only a limited range of storage was possible. To raise the lake level greatly would mean flooding much of Queenstown, and to lower it would mean extremely heavy excavation of several miles of the Kawarau River. The highest known flood level, that of 1878, was fourteen to fifteen feet above what was thought normal. It was proposed that this flood level fixed the highest level of the lake. A dozen houses, two stores, a police station, a small hall, a hotel and playing fields in Queenstown would have to be resited. The proposal became public and aroused immediate opposition. A once-in-a-century flood was one thing, but neither it nor natural seasonal changes altered the lake shore to anything like the same extent as would repeated fluctuations over the range proposed. It was decided to leave Lake Wakatipu alone, and the control gates have not been operated since Roxburgh was built.

Some engineers felt very strongly that if Lake Wanaka was not controlled, Roxburgh was not worth building. Davenport was privately critical of Wanaka residents who wanted the project to go ahead and did not care about Lake Hawea, but would tolerate no change in their own surroundings. In 1949 it was decided not to include control of Wanaka as part of the Roxburgh project. This had more to do with difficult foundations at its outlet than environmental considerations. Lake Hawea was controlled in the late


ROXBURGH
CONSTRUCTION VILLAGE
N
Ambulance
Fire Station
Baths
Cinema
Community Centre
Shops
Police
Sports Ground
Pavilion
School
No. 4 Camp
Cookhouses
No. 2 Y.M.C.A.
No. 3 Camp
Stock Piles
Batching Plant
Dam
Cableway
Powerhouse
No. 1 Y.M.C.A.
Bailey Bridge
Tennis Courts
Company Hostel
Hostel
Churches
R.C.
C.E.
Pres.
CLUTHA
RIVER
Administration
H
Cookhouses
COMMISSIONERS FLAT
Aggregate Stock Piles
Lookout
Spillway
Outdoor Station
Workshops
Site for permanent houses
No. 2 Camp
No. 1 Camp
Coal Creek
Screening Plant
Steel Yard
To Queenstown
To Milton
0
1/4
1/2
Scale of Miles

A temporary hydro town for a peak population of more than 3,000 was built at Roxburgh. This drawing shows the layout of the town and public works camps, and the facilities provided for what was said to be the most modern town in Central Otago.
B. H. Farrell, *Power in New Zealand*

1950s, allowing installation of the last four units at Roxburgh.

A large 'model village' complete with electricity, sewerage and water mains was built at Commissioners Flat, just below the gorge. Roxburgh Hydro, described as the biggest and most modern settlement in Central Otago, was built extremely rapidly, especially considering the difficulties of the post-war years. However, as one observer described, such hydro towns had an air of monotony and only semi-permanence about them, with houses of identical design sited on treeless plots.[2] By the end of 1950, 720 workers were employed on the project and the population of the settlement was 2,000. The population of the village reached 3,120 at its peak in the mid-1950s, by which time there were four single men's camps, with serried ranks of 10 × 8 feet huts for 900 men, cookhouses and a YMCA. Each hut had a stove, bed, table and stool. The 'village' itself comprised more than 700 houses for married men and staff, of a size and design that varied according to the status of the occupant. Wage workers got two-bedroom, 520-square-foot houses rent-free. Some Ministry of Works officials and professionals lived in larger, three-bedroomed houses of 820 square feet in Bendigo Crescent at the northern end of the village. Senior staff lived in Teviot Street and Sandy Point Road ('Snob Alleys') in houses of 1,000 square feet. Many of the houses were later dismantled and shifted to Otematata. The village included a social hall, post office, ten shops providing a good range of services, a sports ground, community centre, cinema, several churches, a library, swimming baths, a TAB, doctor and a district nurse, and a primary school with a roll that reached 550.

A distinctive feature of the project was the diversity of nationalities represented amongst the workers. In 1954, when the numbers on the project were at a peak of about 1,400, 40 per cent were New Zealanders, 36 per cent recent immigrants and contract workers from Britain, and 11 per cent Dutch, with the remainder coming from a host of other countries. Roxburgh Hydro was a typical temporary boom town. There was a disproportionate number of males, particularly single men between twenty and 40 years old, and the age structure was concentrated into the working age groups and young children. Teenagers and older people were largely absent.

In July 1949 the Ministry of Works made a start on the diversion channel, which was to be 100 feet wide and 70 feet deep and involved the removal of 600,000 cubic yards of material. Throughout most of the project work was carried on 24 hours a day and six days a week. Unlike the Waikato schemes, foundations were not a major problem; the diversion of the massive Clutha River was more of an issue. Its average flow was triple that of the Waikato, and the spillways had to be designed for a flood of 150,000 cusecs, five times that considered possible on the Waikato. The design of Roxburgh was revised, with the two diversion tunnels that had been proposed being replaced by a combined spillway and diversion channel, and the powerhouse moved to a more central position. Three very large spillways were to be closed by very heavy counterbalanced gates. A critical shortage of design staff, labour and materials seriously slowed progress and resulted in consideration of contracts for both labour and materials being let overseas.

In May 1949 the Labour Cabinet reluctantly accepted that some large works might have to be undertaken by overseas contractors. French, Danish and British firms expressed interest. A British consortium proposed bringing its own skilled men together with prefabricated housing, and offered to take on the project in its entirety, including the design, civil and electrical work, transmission lines and substations. Nash took a long time to make a decision, while an angry and desperate Semple pleaded in vain for haste. In September 1949 the consortium's offer was rejected; there had been no guarantee on a completion date, the cost was likely to be high and the contract would have involved huge amounts of overseas funds.

Tenders for the main generating plant came in 1950. By the following year it seemed clear that the original aim of having two units in service for the winter of 1955 could not be fulfilled if the Ministry of Works continued with construction. It was also apparent that in the immediate future the South Island's power position was going to become more serious than that of the North, since its growth in demand was closer to 10 per cent than 5 per cent.

Every effort was made to speed up the Roxburgh project. The major problem was the shortage of labour. The entire New Zealand construction industry was overcommitted. There were just not enough skilled men in the country, and even unskilled labour was in short supply, with men unwilling to work on hydro-electric sites. At that time several other major hydro-electric projects were under construction. It was decided that New Zealand should again look overseas, perhaps to the United States or England. Goosman and the recently elected National government were less resistant to the use of overseas contractors than Labour had been.

In late 1951 the Commissioner of Works made an overseas trip that led to tenders being received from both countries. Much the lowest tender — a quarter less than the Ministry of Works' own estimate — came from the British construction firm of Holland and Hannen and Cubitts, in association with the Swiss electrical firm S.A. Conrad Zschokke. (This was a 'target estimate' tender incorporating incentives for rapid completion. In this type of contract the contractor nominated an estimated price, on top of which a fee would be paid. If the job was done for less than the estimate, the contractor would receive a proportion of the savings. If the estimate was exceeded, the fee would be reduced.) Some concern was voiced about the figures and the British firm's lack of experience with large dams, but the tender was awarded to the consortium in July 1952 and it took over at the end of September. By this time the Ministry of Works had completed the excavation of the spillway foundations and excavated and partly lined the diversion channel. The consortium brought some 82 English and Swiss staff and 322 workmen with them. The completion date was to be mid-1955.

Work continued on the diversion channel and the installation of the main construction plant. A 'Johnson' concrete batcher producing 140 cubic yards an hour was shipped in from the United States to provide the enormous quantities of concrete required. This plant, which had been originally used in the reconstruction of Pearl Harbor during the war, subsequently gave good service on both the Benmore and Aviemore projects. In 1952–53 the numbers employed rose from about 500 to more than 1,000. Ministry of Works staff now had a new and difficult role as inspectors. Various problems arose and progress was slow. It was impossible to maintain any running comparison between target and actual expenditure, there were no target estimates for each job and no provision for shift work. Anything done outside the standard eight-hour day and five-day week had to be paid for at overtime rates. Disputes also arose over living conditions.

In March 1953 the Ministry of Works Project

Engineer wrote an extremely critical report. The whole mechanical side was 'woefully weak', with inexperienced staff, and the electrical work was being done poorly. The English management seemed to have little idea of what to do. Other than the Swiss engineers, key personnel seemed to be lacking in skills. Problems were particularly evident on the spillway, where most of the workers did not speak English. The inspecting engineers were insistent on as high a standard of finish for the spillway concreting as at Maraetai, and were concerned about concreting practices. The 'incentive bonus scheme' was said not to have resulted in increased production but rather to operate as a device for raising wages. There was also a long list of complaints about other lax labour practices, including late starting and early finishing, and the taking of long 'smoko' periods or 'crib-times'.

Not enough progress had been made after nine months, even though the labour situation had improved. Ministry of Works engineers became increasingly convinced that management was the key to the problem, but there seemed no obvious alternative to the existing contractor. In May 1953 the Engineer-in-chief wrote to Cubitts in England leaving no doubt about his anxieties over quality and progress and advocating more use of Swiss skill. By July the only solution seemed to be reorganisation of the management, and in particular the removal of the General Manager, who appeared to know little about hydro-electric work and could neither delegate nor manage.

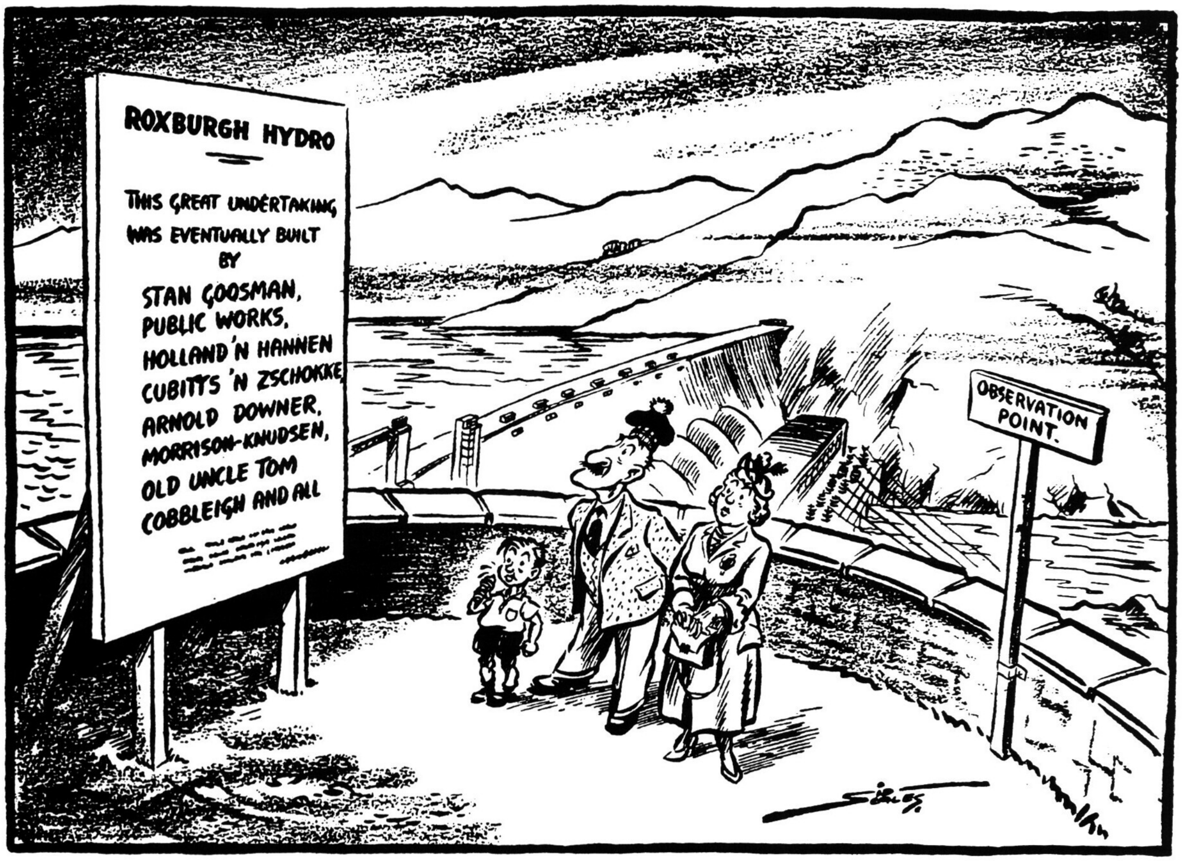
The General Manager despatched senior staff to confer with his principals in England. Directors of both firms arrived in November and were told that if the situation was not remedied officials would recommend that the contract be terminated. There was a growing disparity between target and actual costs, and the completion date was rapidly receding. The contractor would get neither fee nor profit, while the government would have to pay substantially more than it had agreed to.

A new American construction superintendent arrived in February 1954 and found the situation to be disastrous. There were too many men on the job, and much equipment was in extremely bad condition, having been run until it was nearly falling apart. He also thought the control exercised by the Ministry of Works far too tough, even if this was understandable; there would have to be an improvement in relations between the ministry and the contractor's staff. The dilemma seemed insoluble. If the contract was terminated there would be lengthy arbitration and considerable costs. New contractors would have to be found because the Ministry of Works itself was in no position to complete Roxburgh.

One possibility was to bring in a firm with local knowledge and proven reliability. A. F. Downer's company, in association with Morrison-Knudsen of the United States, had previously put in the lowest of the 'schedule of rates' tenders for Roxburgh. Since then they had undertaken with success the addition of two units at Waitaki. A new 'schedule of rates' contract was drawn up for the completion of Roxburgh, with a new target date for lake filling of February 1957. Downers became partners with the existing consortium and A. F. Downer himself took over as Project Manager.

The Ministry of Works had not yet completed the diversion channel, excavation having revealed that additional work would be needed. Good progress was made in 1954–55, with rapid concreting that broke records. On 1 July 1954 the river was finally diverted after many delays and work took on a renewed sense of purpose. On that day the river was rising and well above the low flow that had been hoped for. The narrow walls at each end of the channel had already been dynamited, and at midday nine bulldozers began frantically to push stockpiled spoil into the river channel, with the assistance of about 200 men. At 9 p.m. the abandonment of the bridging attempt was discussed, but it was decided to press on. At 3 a.m. the gap suddenly narrowed, and after eighteen hours work the channel was closed. The upstream and downstream coffer dams were now quickly completed to their full height, and the pond was dewatered to allow foundation excavations to take place. Considerable grouting of foundations was required, and a cut-off curtain extending up to 200 feet below the foundations was created. Sluices were built in the base of the spillway structure, leading to a long three-lane channel, which ended in deflectors. The construction of the dam now speeded up and the left bank soon reached crest level.

For almost a year industrial relations were much improved, but when shift arrangements were altered in April 1955, the men 'worked to rule' at eight hours a day and five days a week. However, the issue was resolved within a few days by a return to the previous conditions. The most significant strike came at the end of 1955, when there was a dispute over smoko arrange-



ROXBURGH FAIR

During the construction of Roxburgh many problems were experienced with the British contractor, Holland and Hannen, and in 1954 the local firm Downers, in association with an American firm, Morrison-Knudsen, was brought into the consortium.
Sid Scales, *Otago Daily Times*, 6 May 1954

ments. This lasted four weeks and set work back considerably.

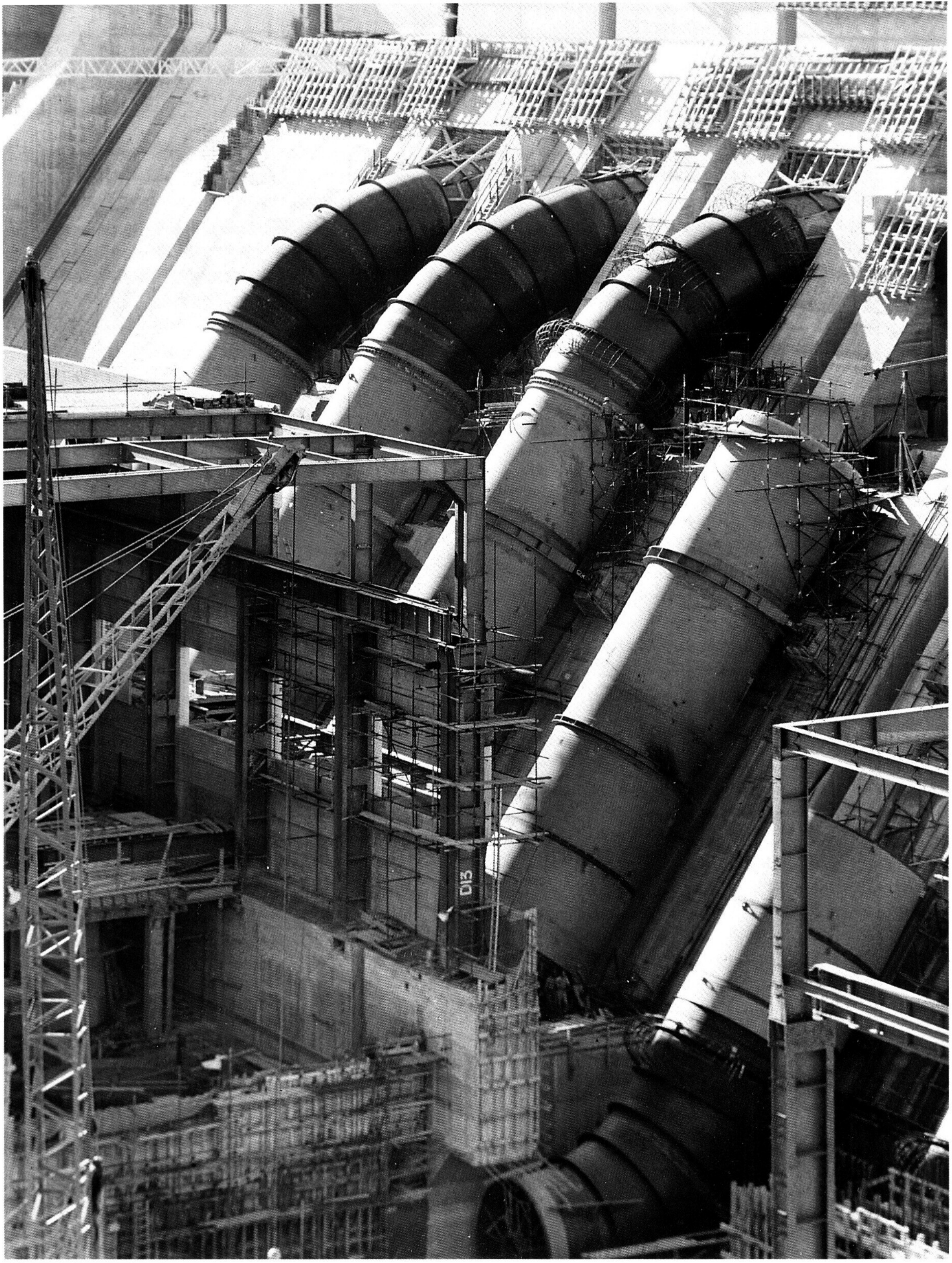
By this time construction of the powerhouse was going ahead rapidly. The turbines, each weighing 220 tons, were installed as soon as possible. (Units larger than 40 MW were not practical because of the difficulties of transporting them.) The deep riverbed 'gullet', where much broken rock had to be cleared out, was dewatered and the dam foundations were finished. Filling of the gullet took an unprecedented ten days of continuous pouring of 15,000 cubic yards of a special concrete mix.

By early 1956 the dam was three-quarters complete and the powerhouse was half finished. It had been another record year of concreting. Some 750,000 cubic yards of concrete in all were used for the project. To overcome the problems of cooling the large mass of the dam, special pipes were laid in the concrete and chilled water was pumped through them. Lake filling began ahead of schedule on 15 July, but had to be suspended while additional grouting was done.

The first power from two units became available on 23 July 1956, and the scheme was officially opened by Goosman on 3 November in the presence of 600 official guests and many members of the public. At the appointed moment,

> slowly the great gates lifted and the water began to skim at high speed down the spillways and into the long, narrow channels. Gradually the flow increased to a surging torrent, drowning speech. Then there came the climax, when from the end of each channel the surging mass of water was shot out high into the river stream in a flying mass of foam and spray as it struck the deflectors.[3]

The first four units, providing a total of 160 MW, were installed by December, and another four were ordered.



Above: A close-up view of five of the eighteen-foot-diameter steel penstocks at Roxburgh in the process of construction.

Opposite above: A view of the upstream face of the Roxburgh dam, showing at centre right the three-lane spillway and at left the intakes for three of the penstocks with a crane in front.

Opposite below: This view taken in October 1955 shows the partially complete Roxburgh dam, and at its left the huge diversion channel (incorporated into the spillway) built to cope with the flow of the Clutha River. At centre the steel penstocks and the powerhouse beneath are being constructed. Sections of penstock lie downstream awaiting assembly at the right bottom.

Whites Aviation

It had been announced in February 1953 that the level of Lake Hawea was to be controlled. This work was done between 1956 and 1958, and involved the building of an earth dam 1,312 feet long and 104 feet high across the lake's outlet, together with four concrete sluiceways. It raised the lake by 60 feet and controlled it over a range of 26 feet. The last four units for Roxburgh were installed during 1961–62, after this storage in Lake Hawea had been provided. In practice the lake has been operated almost invariably over the upper half of its range, except in the winters of 1964 and 1976–77 when it was drawn down to low levels because of drought in the South Island.

The commissioning of Roxburgh removed entirely the need for power restrictions in the South Island and ensured a surplus of power in the south for some time to come.

Clyde

By 1962 most North Island investigations were drawing to a close. The projects resulting from these were expected to meet demand until the mid-1970s. In October 1962 the Cabinet Works Committee gave approval for further investigation of the Clutha River, and this began in 1963.[4] Roxburgh had now reached its full capacity, and Lake Hawea had been raised and controlled. The potential of the Clyde site had already been recognised, and there were other possible sites for dams.

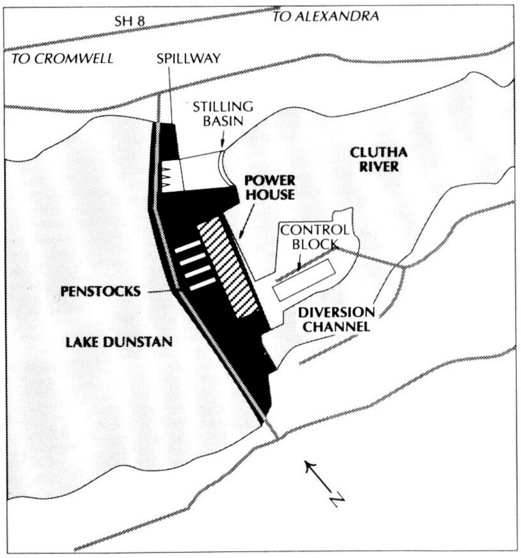
The Clutha River was an obvious candidate for further development. Its water flows had now been recorded for many years. About one-fifth of its annual mean flow went over the Roxburgh spillway unused, and further lake storage was needed to utilise the high summer flows. The question was whether Lake Wanaka would be kept within its 'natural levels', and, indeed, what these in fact were. There was concern that they might be defined as up to the level of the greatest known flood, that of 1878. By this time, however, it was widely recognised within government that it was undesirable, indeed politically impossible, to obtain the maximum possible storage.

In November 1965, after local protest had emerged, Tom Shand announced the investigation of a proposal for five dams: one at Tuapeka (or perhaps Beaumont) below Roxburgh, one at Clyde, a dam on the Kawarau, another on the Clutha a few miles above Cromwell, and one further up at Luggate. Hawea, he suggested, might suffer large changes in level.

However, control of Lake Wanaka would be most important, since nearly half of the Clutha's water came from this source. Some additional storage was regarded as essential for further hydro-electric development on the Clutha, and it would allow Roxburgh to generate more energy. Although Lake Wakatipu provided 40 per cent of the water in the Clutha, it was not feasible to change its level. Shand suggested that Lake Wanaka should be built up in the spring thaw, held at that level in the summer and autumn and drawn down in the winter, all this within 'natural limits'.

An inter-departmental committee was set up in 1967 to look at the likely hydro-electric developments and how they might affect farming, irrigation and other resources of the Clutha Valley. The possibilities assessed ranged from, at one end of the spectrum, a series of five dams between

Clyde: Constructed 1979–90. Head 60 metres. New Zealand's largest concrete gravity dam, it is 490 metres long, 102 metres high and 68 metres wide at its base. Some 1 million cubic metres of concrete were used in the dam and another 200,000 cubic metres in the powerhouse. A slip joint in the dam where it crosses the river channel fault allows up to 2 metres of movement. There are four penstocks, 7.8 metres in diameter. Four turbines drive 108 MW generators, giving a total capacity of 432 MW, with provision for another two units. There is also a 4.9 cumec intake for the Earnscleugh irrigation scheme.



Tuapeka and Luggate with relatively minor impact on existing land use, to, at the other end, a high dam (the Cromwell dam) immediately downstream from Cromwell, which would flood the town.

The committee met the Cromwell Borough Council and the Vincent and Lake County Councils early in 1968, and assured them that no concrete proposals had been made and no decisions had been taken. But it was already clear that any large-scale development of the Clutha would have a greater impact than any previous hydro-electric scheme, especially in a climate of growing environmental awareness.

After simmering away for several years a storm of protest erupted in 1968, much of it based on an assumption that decisions had already been taken. The uncertainty seemed only to worsen the situation. The Otago press was in a constant ferment, especially the *Otago Daily Times*, which was relentlessly hostile. In 1969 the Ministry of Works said that only 'office work' had been done on a high dam at Clyde at the lower end of the gorge, but that this might have very considerable economic advantages. Although the ministry wanted to start actual investigations in the gorge just below Cromwell, Shand stipulated that these should not start until 1970.

Shand considered that he had been free with what little information there was, and that there would be plenty of opportunity to debate firm proposals when they were made by a future government. He observed ruefully that the storm had arisen when it did because of his determination that decisions about power from the Clutha would only be made when all relevant information was available. The inter-departmental committee's problem was more that it was brutally frank than that it was secretive. J. H. George, the local National MP, introduced a private member's bill to preserve natural levels and to prevent any control of Lake Wanaka. The bill was read twice and received with some sympathy, but did not progress further. The 1969 conference of the National Party, with its many rural interests, seethed over such issues as the loss of large areas of fertile land and the envisaged resettlement of whole communities.

The new Minister of Electricity, Percy Allen, who took up office at the end of 1969, felt able to say that the government preferred to combine reasonable economy with a tolerable loss of land rather than simply taking the cheapest option, but he too would give no assurances about decisions that were years away and would be taken by a future government.

The inter-departmental committee's report was finally published in May 1972, and its contents caused no great surprise. A number of possible schemes were described: six above Roxburgh and four below. The perceived effects of each on a wide range of economic activities, including irrigation, as well as on population, local authorities, water supply and sewerage were examined. No recommendations were made, but the schemes were ranked according to the impact they would have. For the upper Clutha, Proposal D, involving a dam at Clyde, another at Cromwell, three on the Kawarau and another three on the upper Clutha, would have the least impact overall and was the one for which the government authorised further investigations. This proposal would involve the flooding of most of the apricot orchards in the Cromwell Gorge, the Lowburn Flats just above Cromwell on the Clutha River, and the lower parts of Albert Town below the outlet from Lake Wanaka.

At this time public opinion at large was hostile, except in Cromwell. Its businesspeople in particular seemed to accept development, did not object to partial inundation if this meant getting a new business centre, and foresaw that the town would prosper during the construction period and would later become an attractive tourist and holiday resort.

At Wanaka, on the other hand, widespread suspicion remained. Many still believed that the lake was to be raised to the 1878 level, and even those with a better understanding of what was involved were opposed to the manipulation of its level. They feared it would become like Lake Hawea, where significant changes in level had resulted in 'dust-bowl' conditions in high winds. The Electricity Department recommended further serious investigation of Scheme D and variations of it, and of one of the lower Clutha schemes, minus a dam at Barnego near Balclutha, which would have had a severe impact on the area. The department preferred development of the upper Clutha.

Cabinet set up a liaison committee linking government departments and local bodies, a Wellington-based steering committee, and a local working committee in Dunedin in an attempt to improve consultation. It was well aware of the political risk it was running; the controversy was a gift to the Labour Opposition. How much influence the debate had on the outcome of the 1972 election is difficult to determine, but the 'storm over the Clutha' was certainly a major element in National's loss of its 'safe' seat of Otago Central.

The newly elected Labour government had made a number of specific promises, including protection of Lake Wanaka by legislation and the establishment of an independent commission to assess all Clutha Valley resources. Its Minister of Works, Hugh Watt, was committed not to raise Lake Wanaka, not to flood productive land in the Cromwell Gorge and not to build hydro-electric dams below Roxburgh. The Electricity Department argued in vain against the Lake Wanaka Preservation Act, preventing any control over the lake, which became law in November 1973, but by now politicians of all hues claimed that they had never wanted to build control works there. The Clutha development first appeared in the Power Planning Committee's reckoning at this time, with 100 MW due to be produced in 1982.

The Clutha Valley Development Commission was established in October 1973 with a brief to look at the development of resources from the lakes to the sea, to recommend suitable hydro-electric development above Roxburgh and to identify opportunities for more intensive land use, industry, tourism, recreation and community development. The commission produced its report in November 1974.

Eight possible proposals were looked at, although for practical purposes they could be reduced to Schemes H and F. (Scheme D was no longer possible because it had depended on the control of Lake Wanaka.) Scheme H, which would produce 1,490 MW and 4,275 GWh, involved two dams in the Cromwell Gorge, one just below Cromwell and another 'low' dam at Clyde, dams at Luggate and Queensberry and two on the Kawarau River. Although much of Cromwell's existing business district would be flooded, along with Lowburn (but to a lesser extent than under Scheme D), most of the orchards in the Cromwell Gorge would not. Scheme F was similar to Scheme H but eliminated the Cromwell dam and included a 'high' dam at Clyde (where the conditions for foundations were better) and the same four other dams. This scheme would yield a greater capacity and be cheaper and quicker to build. Both would flood about the same amount of farmland overall, but Scheme F would inundate the 86 hectares of the twelve apricot orchards in the Cromwell Gorge. The commission recommended Scheme H. Cromwell, as the centre of construction, would be expanded and established as a permanent regional centre with housing of a high standard. Schemes for the irrigation of up to 45,000 acres should be developed alongside the power project.

The Ministry of Works and Development's Environmental Impact Report of May 1975 on Scheme H was strongly criticised by the Commission for the Environment. Even before the commission's audit had been published the ministry sought approval in principle for the Cromwell dam and Scheme H, so that plant and manpower could be transferred from the Manapouri and Upper Waitaki projects. In September the ministry asked for a decision on which scheme was to be pursued and approval for the expansion of Cromwell and the investigation of irrigation schemes. Meanwhile the ministry was beginning to develop a preference for Scheme F, which was to grow stronger as investigations of the Cromwell dam site uncovered difficulties.

The Commissioner for the Environment had strong support from two Ministers who were particularly committed to the Labour government's promises on environmental issues. There was no agreement in Cabinet and the matter was returned to the officials, who were also arguing among themselves. The Commissioner for the Environment maintained his views, while the Ministry of Works and Development, the Electricity Department and Treasury all agreed that on economic and technical grounds Scheme F was preferable. The Electricity Department, however, thought that on environmental grounds the decision should be for Scheme H.

In September 1975 Cabinet decided on Scheme H, but within a few months the government had changed again and the Otago Central seat had gone back to National. In Opposition the National Party had promised to set up a Clutha Valley Authority and to review both the decision to build the dam just below Cromwell and its height, which the new MP for Otago Central had pledged to have reduced. The review took place, but only among Ministers and officials. Early in 1976 the Ministers most concerned visited the Clutha Valley, and as a result asked for another scheme that would generate as much electricity as Scheme H but save Lowburn and the farmland. The Cromwell Gorge orchards could be flooded and Lake Wanaka controlled. The new low-dam scheme that emerged was known as NV1. It would, in fact, flood part of the Lowburn Flats but neither Cromwell nor the Lowburn township; nor did it rely upon control of Lake Wanaka.

It included further dams on the Clutha and Kawarau Rivers and would be considerably more expensive than either Scheme H or Scheme F. In June a Clutha Valley Advisory Committee, made up largely of local authority representatives, was set up as a precursor to the Clutha Valley Authority. Its task was to advise on the merits of Schemes H, F and NV1 and recommend one of them. The committee, reporting in October, supported Scheme H by a majority decision; three of its eleven members submitted a minority report saying that they could not make any recommendation.

The decision now fell to the Prime Minister, Robert Muldoon. All the schemes were problematic: NV1 could be forgotten, since the Lowburn people it had been intended to help turned out not to want it; Scheme H had always been an unsatisfactory compromise; and the problem with Scheme F remained the loss of the orchards in the Cromwell Gorge.

In the event Cabinet approved Scheme F on 20 December 1976. They were surprised by the resulting uproar but did little about it. The government, in essence, gave up all hope of winning over public opinion and decided to do what it thought best. In March 1977 approval was given for the expansion of Cromwell by 1,000 houses, and in May it was decided to go ahead with preliminary works on the premise that these would be necessary whichever of the two schemes was carried out. These works included an upgrading of the state highway through the Lindis Pass, the construction of access roading and a major highway bypass of Clyde, purchase of plant, the establishment of works in Cromwell and (if possible) the purchase of orchards.

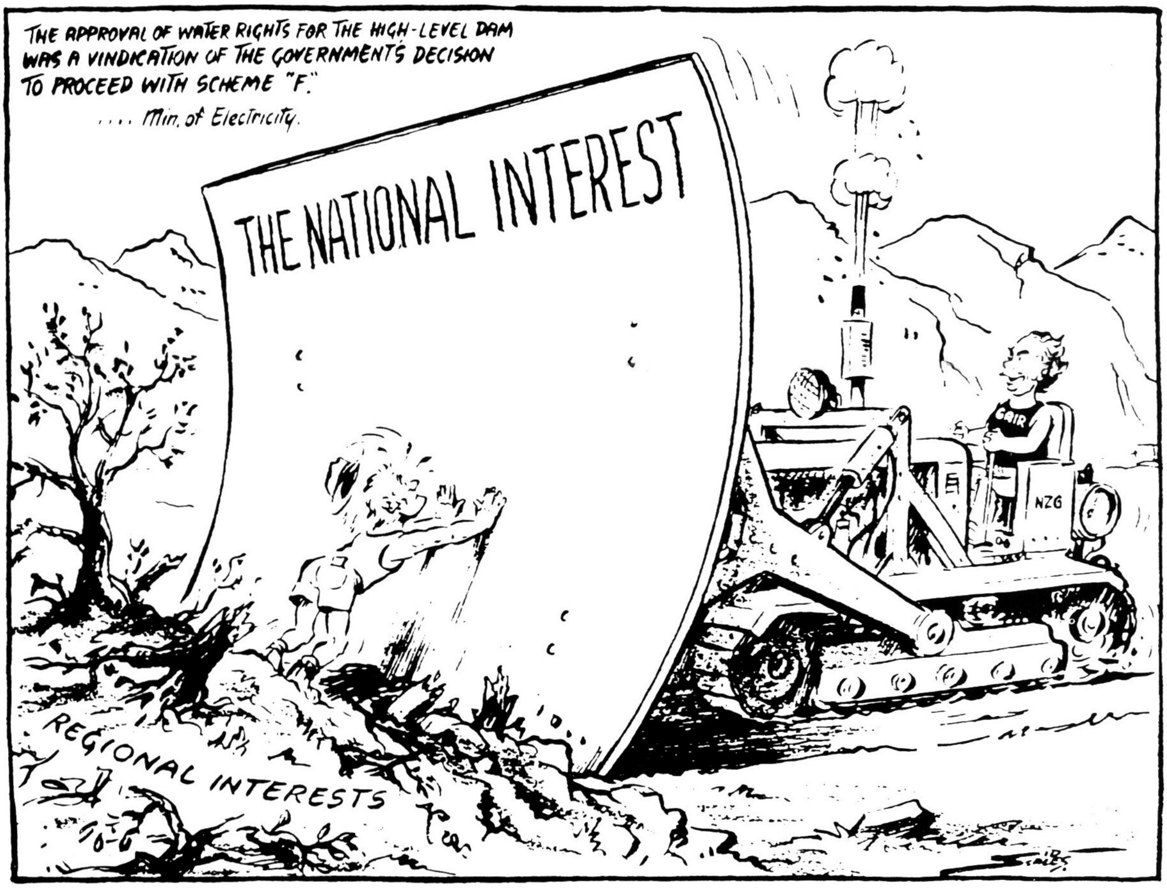
A water right for the Clyde dam was sought in the usual way. The first step involved an application to the Otago Catchment Board, which insisted that it could recommend a variation in the height of the Clyde dam rather than simply consider an existing proposal. The board saw itself as the only authority embracing the whole Clutha catchment, and as therefore representative of local and regional interests. It received 209 public submissions, all but three of which opposed the application. Many of these found Scheme H acceptable, a position received with some scepticism in Wellington, where it tended to be thought that if the orchards were saved the campaign would switch to Lowburn. The catchment board recommended that the National Water and Soil Conservation Authority refuse to issue a water right for a 'high' dam, but grant one for a lower dam.

The authority, which was chaired by the Minister of Works and Development, held that it could not grant a water right for a lower dam if it rejected one for a higher dam. Its task was to determine whether the proposal was in keeping with the Water and Soil Conservation Act. The authority decided that it was and had little difficulty in accepting that the extra power and economic advantages of Scheme F would justify the losses involved. In December 1977 the authority granted the application subject to requirements for a fish hatchery and water for irrigation, which the Electricity Department found acceptable.

In February 1978 objectors lodged seventeen appeals with the Planning Tribunal. By this time it no longer seemed necessary to supply additional power urgently to Comalco, and a target date of winter 1980 for diversion of the river was acceptable. In July 1977 the Supreme Court had begun to hear actions by an affected orchardist, and in April 1978 it started hearing appeals that had been lodged with the Planning Tribunal. The court was asked to review the Conservation Authority's decision to grant a water right. The Ministry of Works and Development was by now concerned about the situation, as the procedures of the Town and Country Planning Act 1977 would soon be in force and would introduce the possibility of new delaying tactics.

In April 1978 the ministry sought money to continue with preparatory work, including the purchase of land. The Commissioner for the Environment protested, on the grounds that an impact report on Scheme F had not yet appeared. Ministers felt that any perceived deferral would destroy their credibility with people in the Clutha Valley, most of whom now seemed to be at least reconciled to the dam. Some land had been offered voluntarily and not to buy it would breach undertakings given and damage the government's reputation. The money was granted.

The usual environmental assessment procedures were not undertaken. It was argued that keeping to the original commissioning date of 1985 would not allow time for this. There would be no impact report or audit on Scheme F as a whole, but rather a series of reports on its individual parts. A Clyde Dam Report duly appeared in April 1978. The Commission for the Environment's audit included some forceful comments on such procedures but stopped short of saying that statutory rights had been eroded.


THE APPROVAL OF WATER RIGHTS FOR THE HIGH-LEVEL DAM WAS A VINDICATION OF THE GOVERNMENT'S DECISION TO PROCEED WITH SCHEME "F."
.... Min. of Electricity.
THE NATIONAL INTEREST
REGIONAL INTERESTS
GAIR
NZG
Scales

DRIVING BLIND

In 1977 the National Water and Soil Conservation Authority controversially approved water rights for a high Clyde dam as part of the wider Scheme F proposal for developing the upper Clutha. This cartoon shows the Minister of Electricity, George Gair, using a Ministry of Works bulldozer to sweep aside regional interests.

Sid Scales, *Otago Daily Times*, 8 December 1977

Many had by now concluded that the government was determined to build the dam whatever the outcome of the legal process. The chairman of the Planning Tribunal asked for an assurance that the government would accept its decision. Falling rates of growth in demand for electricity now made it harder to justify Scheme F, and Ministers began to paint a glowing picture of electricity-intensive industries. The Crown Law Office became anxious to avoid a situation in which any decision by the Supreme Court or the Planning Tribunal would later be overridden by the government. Its opinion was that Ministers should consider enacting specific empowering legislation or declare the project to be of national importance. Alternatively, the Water and Soil Conservation Act might be amended to provide that certain Crown applications for water rights should be determined by the Minister after a report from the Planning Tribunal. In August 1979 Cabinet accepted that the final decision should be the government's and that long procedural delays should not be allowed. It approved the drafting of a National Development Bill to this end.

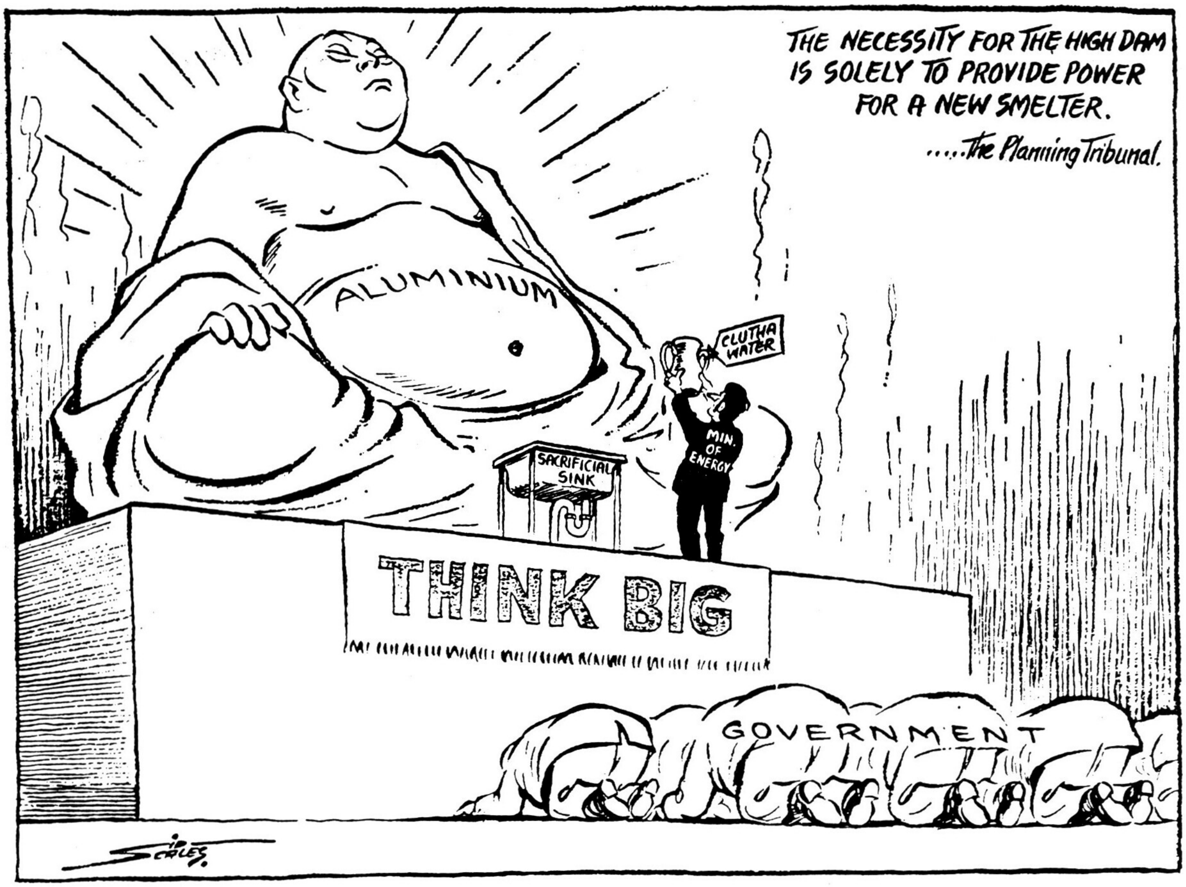
By 1979 the Clyde proposal was not looking particularly attractive. Moreover, Maui gas had to be paid for whether used or not, and would perhaps be better used for electricity than left in the ground. As a result the 1979 Power Planning Committee recommended commissioning be delayed until 1991, even as Ministers were planning to sell off a surplus 2,000 GWh a year and seeking first power by 1989. The new policy to use South Island electricity to establish and develop electricity-intensive industries. such as a second aluminium smelter at Aramoana at the head of Otago Harbour, had now to be taken into account. The subsequently published report on 'growth opportunities' indicated that as much as 5,000 GWh could be available. As a result Clyde's completion date was brought forward to 1988.

Actions in the Planning Tribunal other than those concerning the water right were all disposed of by July 1980. The appeal against the granting of a water right was heard in September–October 1980. The Crown's evidence did not mention the proposal for a smelter at Aramoana, but rather simply argued that power was required for the national grid. The appellants, on the other hand, made a great deal of the extremely controversial smelter project, which according to one economist represented such a poor investment that it would never be built.

The tribunal decided by a majority, with two dissenting, to reject the appeals. It held at one and the same time that the Clyde dam was entirely dependent on a second smelter, and that it could not consider the end use of the electricity for the generation of which a water right was sought. In other words, it could not take into account the argument that the smelter might not be built. However, the tribunal also considered that it should seek the guidance of the High Court on a number of points of law, the most important being whether it had been correct in deciding it could not consider the end use of the power. After eighteen months Judge Casey delivered his celebrated judgment in May 1982. He held that the tribunal was in fact able to take into account the end use of the power, and the appeal was returned to the tribunal for rehearing.

What was to be done? It was not certain that resort to the Water and Soil Conservation Act would get around the blockage. On the Electricity

The Planning Tribunal decided by a majority in late 1980 that, even though it believed that the Clyde dam depended upon the proposed aluminium smelter, it could not consider the end use of the power in the appeals before it. The Minister of Energy, Bill Birch, offers a sacrifice to the deity, while the government bows down before 'Think Big', the major energy developments of the time.
Sid Scales, *Otago Daily Times*, 18 December 1980


THE NECESSITY FOR THE HIGH DAM IS SOLELY TO PROVIDE POWER FOR A NEW SMELTER.
.....The Planning Tribunal.
ALUMINIUM
CLUTHA WATER
MIN. OF ENERGY
SACRIFICIAL SINK
THINK BIG
GOVERNMENT
SCALES

THE GRAVEN IMAGE

Division's figures, Clyde would be needed by April 1987 if Aramoana was built, and even then there would be lower than usual margins of safety in supply. Without the smelter, the Electricity Division estimated that additional power would be needed only a year later; the only other (undesirable) option was the conversion of Marsden B to coal or gas. Any changes to the proposal or additional deferral of its approval would be costly and create still further delays. Resort to Scheme H would be no solution, since the dam site below Cromwell had been found to be problematic and there would surely be a drawn-out fight over the fate of the Lowburn Flats.

The Planning Tribunal wanted an assurance that the National Development Act, passed in 1979 and intended to 'fast-track' major projects, would not be used to override its decision. For the government, the only sure way out of its predicament was through special legislation. But it had a very small majority and at least two backbenchers who were likely to cross the floor on the issue. In June 1982 a Cabinet committee agreed to the preparation of legislation relating specifically to a water right for the Clyde dam after receiving more draconian advice from the Crown Law Office.

It was now increasingly apparent that a simple reversion to Scheme H would not be viable. If a water right for Clyde was lost, the whole development of the upper Clutha would have to be reassessed. Relief for the government came in mid-July when the two Social Credit members of the House agreed, in return for certain assurances, that if the water right was not granted they would help pass the Clutha Development (Clyde Dam) Empowering Bill.

The Planning Tribunal sat again in August, declined to hear any new evidence and, after considering the end use of the power without any evidence that the smelter would be built, declined the water right. The government quickly introduced the Empowering Bill, defending it on the ground that the development of the upper Clutha was of vital importance for the whole country; the smelter was significant only in relation to the timing of the Clyde project. The bill was passed on 30 September 1982 and, having got its water right at last, Clyde could now be started in earnest.

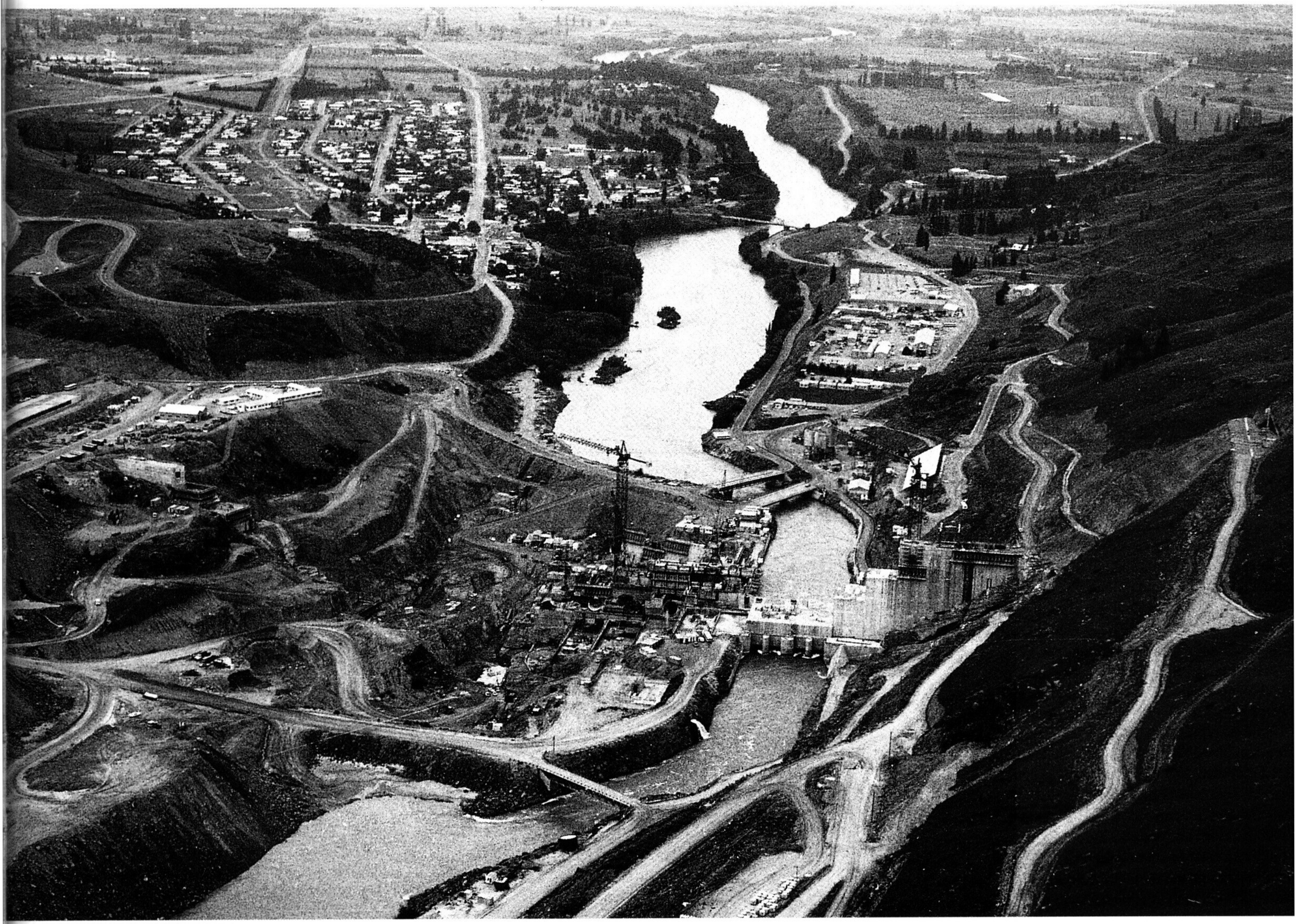
The Ministry of Works and Development had long had the major statutory responsibility for construction work on hydro-electric projects. This did not preclude work being let out as subcontracts, but these were subsidiary to the so-called 'core' works. In the past local private construction firms had been neither large enough nor sufficiently experienced, but now larger firms began to argue that they should be involved. The government decided that the ministry's role in the Clyde project would have to be justified rather than simply taken for granted.

The Contractors' Federation made a particular issue of the Clutha schemes. The ministry put forward its case: no New Zealand contractor had undertaken work approaching the size of the Clyde project, and none had as good a record of industrial relations as the ministry; hence overseas contractors would be required. The Electricity Division strongly supported the ministry's argument. The cost overruns and industrial relations problems at Marsden B had greatly soured its view of private contractors.

In October 1978 the Cabinet Works Committee recommended that the ministry should build the project with its own work-force while ensuring that as much work as possible was given to the private sector. Cabinet, however, did not accept this and decided that the ministry should build only the powerhouse and the right abutment, while the remainder of the dam was let to private contractors. The main reason for this decision seems to have been the Contractors' Federation's insistence that experience in dam building would open the way for New Zealand firms to undertake similar contracts overseas. In the event the New Zealand partner in the Clyde project went into receivership and is unlikely to be involved in any further dam-building ventures; this role is more likely to be adopted by the Works and Development Services Corporation itself.

In 1978 the ministry had made a start on excavation of the right abutment and the diversion channel. Work on the expansion of Cromwell stopped the following year, after several hundred houses had been erected, because of the deferred completion date for the project. The excavation of the diversion channel was completed in August 1979, and earthworks on the left bank were started in August 1980.

Official approval to start preparatory work for the Clyde dam was given in July 1981 prior to water rights being granted. By mid-1982 the diversion channel had been completed and lined with concrete, and the river was diverted in July 1982. Dam and powerhouse excavations were

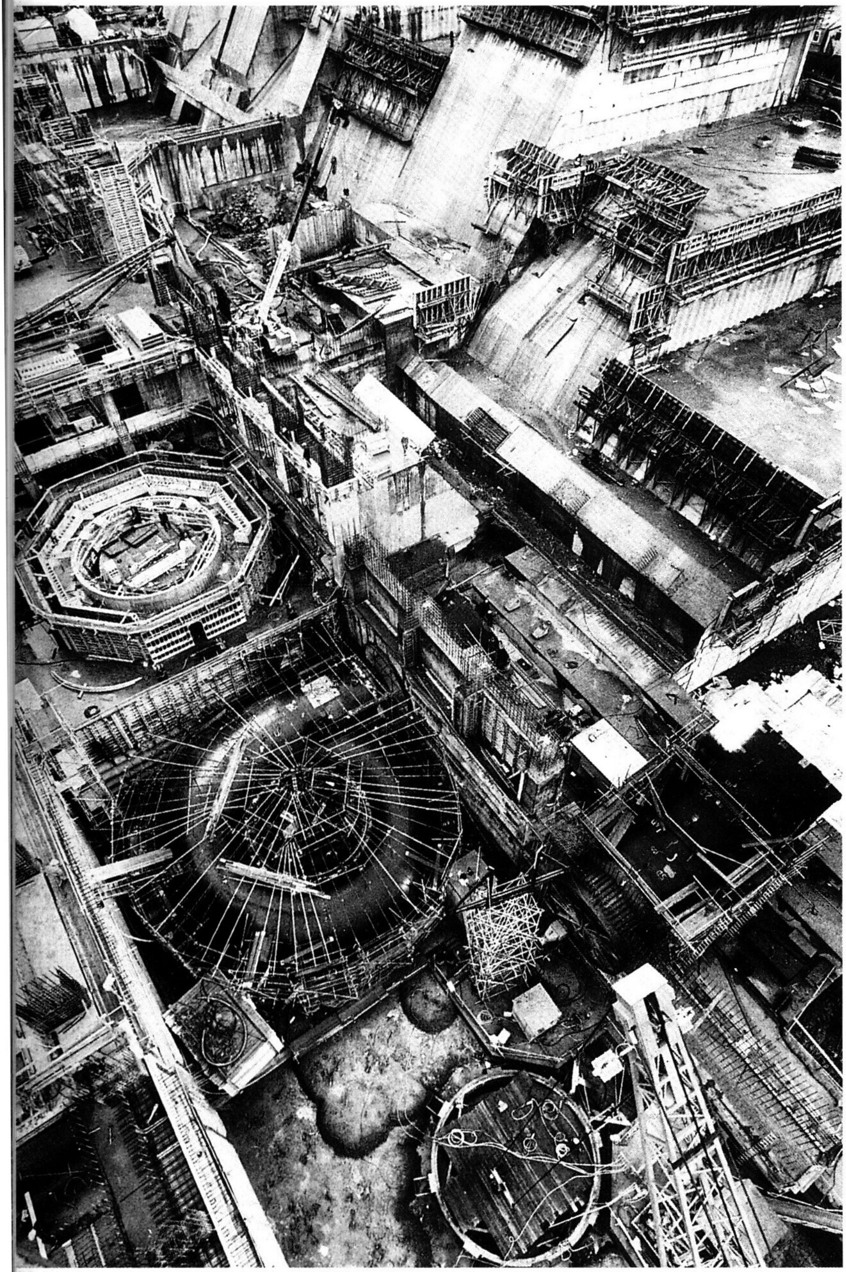


A view of the early phase of construction of the Clyde dam, with the Clutha River diverted and coffer dams formed to allow the excavation of dam foundations. To the right of the diversion culvert can be seen the right abutment of the concrete gravity dam, which was completed by the Ministry of Works and Development before the rest of the dam. Downstream is the town of Clyde, which had been bypassed by the new highway seen in the top left corner.

then begun, after the coffer dams had withstood a major flood. Tenders for construction of the dam closed in January 1982. Following the passage of the Clyde Dam Empowering Act that year, this work was awarded to the Zublin-Williamson consortium and the contract for turbines and generators to Hitachi of Japan.

Once the project was assured of going ahead, the expansion of Cromwell accelerated with the construction of more housing and a new commercial centre, sports ground, gymnasium, swimming pool and secondary school. By 1984 about 500 houses, including 90 from Twizel, had been erected in Cromwell. The new commercial centre was officially opened in February 1985. By 1986 Cromwell's population had grown from the 1,200 recorded in 1976 to 3,500.

Much of the excavation for the dam foundations had been completed by early 1983, by which time concreting of the right abutment was one-third finished and that for the powerhouse had begun. That year an old fault-line was discovered under the dam foundations; this delayed progress considerably and necessitated nearly



Looking down on the turbine spiral casings in the powerhouse at Clyde, with blocks of the dam going up.

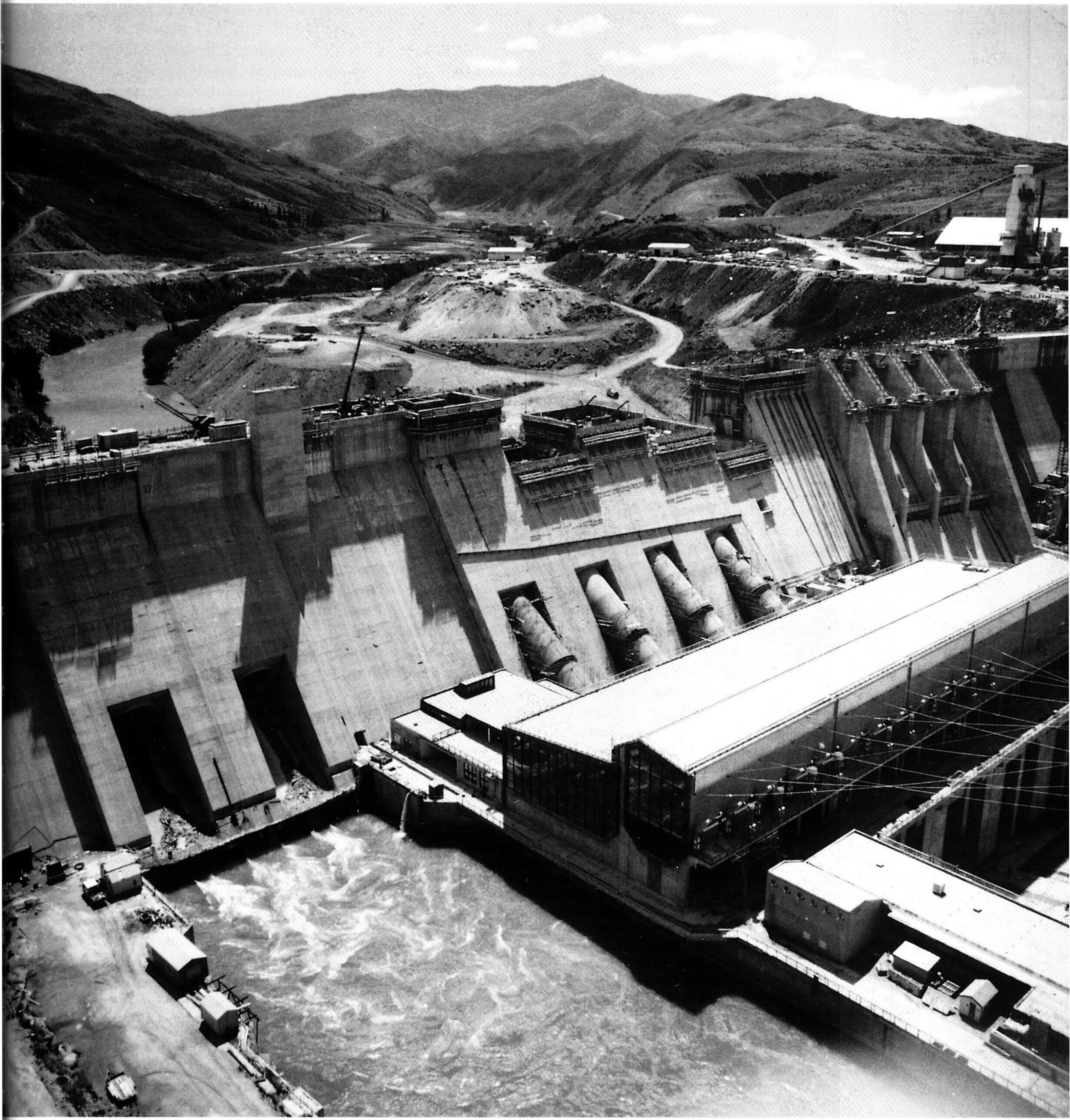
250,000 cubic metres of additional excavations and the driving of tunnels infilled with concrete. This complex extra work was not completed until early 1986. Zublin-Williamson began placing concrete in the left abutment and dam in March 1984, by which time the right abutment was almost complete. The powerhouse was now one-quarter finished.

By early 1986 the project as a whole was half finished, and a year later the work-force reached a peak of 1,200. Good progress had been made on the dam, with 600,000 cubic metres of concrete placed in a year and nearly half of its blocks up to crest height. By early 1988 the project was three-quarters finished, and the last concrete was placed in mid-1989. Several years of dredging were still required to lower the tailrace by four metres and thereby increase the head.

In 1989 the turbines and generators were installed. However, their use must await the filling of the lake. This will take place only when the slopes of the gorge are stabilised, so that when Lake Dunstan is filled there is no hazard. Some two million cubic metres of buttressing, together with thousands of drain holes and several tunnels, are required to strengthen and dewater the unstable areas. The lake will extend 38 kilometres upstream, twenty kilometres past Cromwell up the Clutha and eleven kilometres past Cromwell up the Kawarau. Filling is due to begin in June 1992.

Clyde is the first dam of the Upper Clutha scheme, and may possibly be followed eventually by other dams upriver at Luggate and Queensberry on the Clutha.[5] However, given the current slow increase in the demand for electricity, there is at present no urgent need for further large hydro-electric stations.

Opposite: The almost-completed Clyde dam and the entrance to the Cromwell Gorge. At the bottom the diversion culvert under the dam can be seen. Four penstocks have been installed, and there is provision for two more when the powerhouse is extended over the diversion culvert.



CHAPTER FIFTEEN

Delivering Efficiency

ON 1 APRIL 1987 the Electricity Corporation of New Zealand (ECNZ) came into being, as the flagship of the Labour government's programme to commercialise its trading departments.

In the mid-1980s the Labour government began to deal with the legacy of the major energy projects, a surplus of generating capacity and a strongly regulated economy in which government intervention was prominent. Labour looked at the possibility of reorganising or selling off a wide range of state trading departments in order to improve their performance, give better returns to the government, or reduce mounting debt. The Electricity Division of the Ministry of Energy was a prime candidate for corporatisation.

The McLachlan report completed for Treasury in 1984 signalled this shifting environment. It concluded that the historical expenditure on power stations had led to large unnecessary costs because of inadequate planning, advice and management, and that this had affected the overall performance of the economy. More widely, the Electricity Division was criticised for its excess generating capacity, non-commercial pricing and a lack of emphasis on cost and efficiency.

These assessments were all very well in hindsight, but they did not adequately acknowledge the considerable difficulties that the Electricity Department (and the Ministry of Works) had laboured under in the post-war decades, as discussed in Chapter Six.

Passage of the State-owned Enterprises Act and the removal of the state's effective monopoly over generation in 1986 followed from such analyses that suggested that the state had invested massive sums in trading departments and managed huge assets but made little or no return to taxpayers as a result. As Geoffrey Palmer stated, 'such a state of affairs cannot continue'.[1] This Act enabled the formation of state companies with the objectives of operating as successful businesses by being profitable and efficient, while at the same time being good employers and exhibiting a 'sense of social responsibility'. Having established commercial objectives for ECNZ as a state-owned enterprise (SOE), the key question became the extent to which political considerations would intrude upon the corporation's activities and, following from this, the extent to which the government would publicly support the new enterprise. The expectation for the new corporation was that it would perform more efficiently while investing prudently, and that it would lead the way in the reforms under way in the economy.

Formation

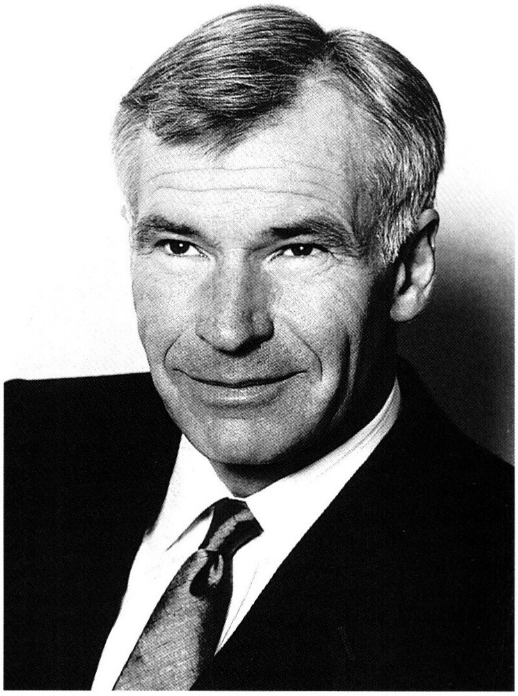
In 1978, in an attempt to improve co-ordination between the Electricity Department, the Mines Department and the Ministry of Energy Resources, the Ministry of Energy was formed, but its various component parts continued to act largely independently. Under pressure from the State Services Commission, in the early 1980s reorganisation of the Ministry began to take place, to separate out the regulatory and trading functions so that the latter could be commercialised. The Electricity Division, as the largest and most entrenched, was left until last; it too underwent a process of review and reorganisation in 1986 to introduce a more commercial orientation.[2] New Zealand's generating infrastructure had largely been completed; the major requirement now was improved operation and maintenance of the system, but the Division's direction was still shaped by engineers with a construction focus.

In August 1986 John Fernyhough was appointed as Chairman of a transitional Establishment Board for the proposed corporation. No bones were made about the magnitude of the task or the changes expected. Advertising for a Chief Executive took place in September 1986 with the job described as 'changing a key government department to a private enterprise company ... operating under commercial principles'.[3] The advertisement continued: 'The appointee will be responsible for bringing about major organisational and attitudinal change. The person will have total responsibility for planned profitable growth'.

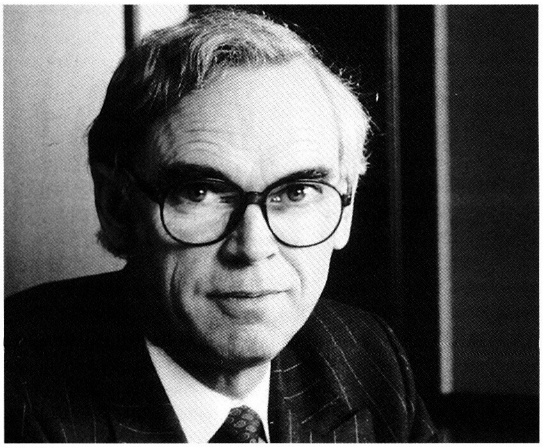
Fernyhough decided that he had to start with a 'clean sheet', and he and the task force he had appointed (which carried out its work in secret) rejected the partly implemented reorganisation as inappropriate for the fully commercial environment in which the corporation would have to operate.[4] The task force's report was released in late December 1986 — to the shock of the organisation — and was adopted in February 1987 as the blueprint for the new organisation. In the task force's view an overly complex, centralised and hierarchical departmental structure had been retained, and it suffered from a lack of accountability and autonomy, inadequate decision-making processes and an inability to identify production costs. ECNZ's subsequent Statement of Corporate Intent made it abundantly clear that the corporation intended to operate commercially to the fullest extent possible and that the organisation would reflect this.[5]

The task force proposed separate decentralised business units with flatter management structures and a profit orientation. Internal competitive 'tension' would be created between elements of the organisation to drive down costs and prepare the corporation to respond to, or even encourage, external competition.

After a long search Dr Roderick Deane, then Chairman of the State Services Commission, was appointed in April 1987, having apparently been headhunted at the last minute. Fernyhough commented prophetically that Deane would 'oversee the development of the corporation into one of the most dynamic companies operating in the country.'[6] He and Deane would make a powerful complementary team and play a crucial leadership role in reform. Fernyhough provided intellectual leadership and a brash media style, while Deane expertly carried out the implementation of the philosophy.



Colin John Fernyhough was born in Wellington on 17 July 1938. He was educated at Christchurch Boys' High School and Rongotai College, and graduated from Victoria University of Wellington with an LlB in 1959, followed by an LlM (Hons) in 1960. He then went to the University of Chicago and was awarded a Doctor of Jurisprudence in 1962. While there he was influenced by Milton Friedman and what became known as the 'Chicago school' of economics. Fernyhough became a partner in the legal firms of Chapman, Tripp and Co., for whom he worked from 1963 to 1968, and Russell McVeagh McKenzie Bartleet and Co. (1968–79), specialising in commercial and company law. He then went out on his own as a barrister in the period 1979–82 before turning to business. He became a Director of the New Zealand Forestry Corporation, Lion Corporation, the Development Finance Corporation and other companies, and was Deputy Chairman of the Securities Commission from 1979 to 1985. He was appointed Chairman of ECNZ's Board of Directors in 1987, having chaired the Establishment Board in 1986, and continued in this capacity until 1993. Fernyhough set the new corporation on a path of radical reform and provided a strong sense of leadership that would equip it well for the future.



Dr Roderick Sheldon Deane was born in Auckland on 8 April 1941. He was educated at Opunake High School, New Plymouth Boys' High School and at Victoria University of Wellington, where he received a BCom (Hons) in 1964 and a PhD in 1967. He worked in the Union Steam Ship Company in the period 1960–63 and became a chartered accountant and chartered secretary. He was a part-time lecturer in economics at Victoria University and Wellington Polytechnic from 1964 to 1978. He worked in the Reserve Bank from 1963 to 1974 before being appointed as Alternate Executive Director of the International Monetary Fund in Washington, DC, for the period 1974–76. He was appointed as Chief Economist to the Reserve Bank in 1976 and became its Deputy Governor in 1982. In 1986 he was appointed Chairman of the State Services Commission with the task of overseeing the restructuring of the public sector. Deane became Chief Executive of the Electricity Corporation of New Zealand in 1987. He served as President of the New Zealand Society for the Intellectually Handicapped (IHC) from 1988 to 1994 and on the New Zealand Board of the AMP Society from 1990-92. Deane was awarded a New Zealand 1990 Medal. In 1987 he became a Fellow of the Chartered Institute of Secretaries and Administrators, and in 1988 a Fellow Chartered Accountant. This was followed by Fellowships in the Chartered Institute of Managers (1991) and in the New Zealand Institute of Management (1992). In October 1992 he resigned from ECNZ to become Chief Executive and Managing Director of Telecom Corporation of New Zealand. For some years he has also been a Director of Fletcher Challenge, Auckland, and of the ANZ Banking Group in Melbourne. Deane's strong and decisive leadership transformed ECNZ's efficiency and gave it a central place in the reform of the electricity industry.

Fernyhough underlined the necessity for surprise and speed to achieve radical reform and a radically different organisational culture. All existing staff would have to apply for restructured positions and new staff would be sought, to create a new culture and allegiances. He described the reorganisation as 'one of the largest and most complex corporate restructurings undertaken in New Zealand within such a short space of time'.[7] Whilst this was a painful and difficult process, it was vital to move away from the previous regime of oversupply, insensitive pricing policies, lack of competition and cost overruns.

In a complete reversal of tradition, Fernyhough put engineers and design and construction at the end of the decision-making chain and the market at the beginning. A completely new top management team was carefully appointed and the upper levels of management were systematically transformed. Many senior engineers left and were replaced by others from the private sector with commercial expertise. Senior management contracts were designed to provide incentives for performance and to allow delegation of authority and responsibility by relating contracts to objectives. Financial management and in particular controlling cost became the central objective. All 6,000 jobs were reviewed and in the end more than a thousand employees took voluntary severance. A year after corporatisation staff numbers had been reduced by one-quarter.

The new corporation was based around three business units — Electricorp Production to operate the power stations, Electricorp Marketing to market the energy, and Trans Power to operate the national grid. The fourth unit, PowerDesign-Build (concerned with design and construction) was constituted as a subsidiary company to ensure the transformation of engineering from the decision-making hub to a separate consulting company. In 1988 Trans Power was also established as a subsidiary company.

Considerable industrial unrest accompanied the formation of the corporation. In late 1987 confrontation developed with the Public Service Association over restructuring and this led to court proceedings, but by the latter half of 1988 seven voluntary agreements covered employees, with separate agreements for the four business units. ECNZ led the way in introducing a new style of industrial relations that reasserted the managerial prerogative and brought in more flexible enterprise-based bargaining.

It took some time for the new industrial relations order to settle down. In 1988 blackouts resulted from an industrial dispute over wage increases. The organisational restructuring, together with negative publicity deriving from the payment of substantial salaries and bonuses, a conference in Queenstown in 1989, and the corporation's refurbishment of its Rutherford House headquarters, created in the public's mind an image of greedy profit-seeking and extravagance. The corporation at first probably put this down to the teething problems associated with introducing and being the flagship for radical reform, and expected matters to settle down. But despite active public relations management, the bad publicity refused to go away.

The corporation, known publicly as Electricorp, soon asserted its new goals in which marketing and the promotion of electricity use would feature more aggressively. Drew Stein, who headed Electricorp Marketing, was keen that ECNZ should seize the opportunity to shift itself comprehensively into the new corporate world. The style in which the corporation conducted its business should reflect the change, and if generous spending on hosting events, running conferences and creating a new image was required then this should take place. But, while this may have started to change attitudes towards the selling of electricity, it also sowed the seeds of mistrust and unease amongst the retail power companies. The gulf in culture and style was too much to bridge. Stein's innovations and special deals strengthened perceptions of the corporation's monopoly market power.

ECNZ's marketing drive sought to increase volumes of electricity sold, compete with alternatives such as gas and coal, and achieve a good rate of return for the shareholder. By keeping prices low the corporation would encourage electricity use, deal with the threat of competition and the surplus of generating capacity would disappear more quickly. In June 1988 the 'Electricity – Simply Brilliant' campaign was launched. This presented electricity in terms of value for money, with messages of convenience and low cost.

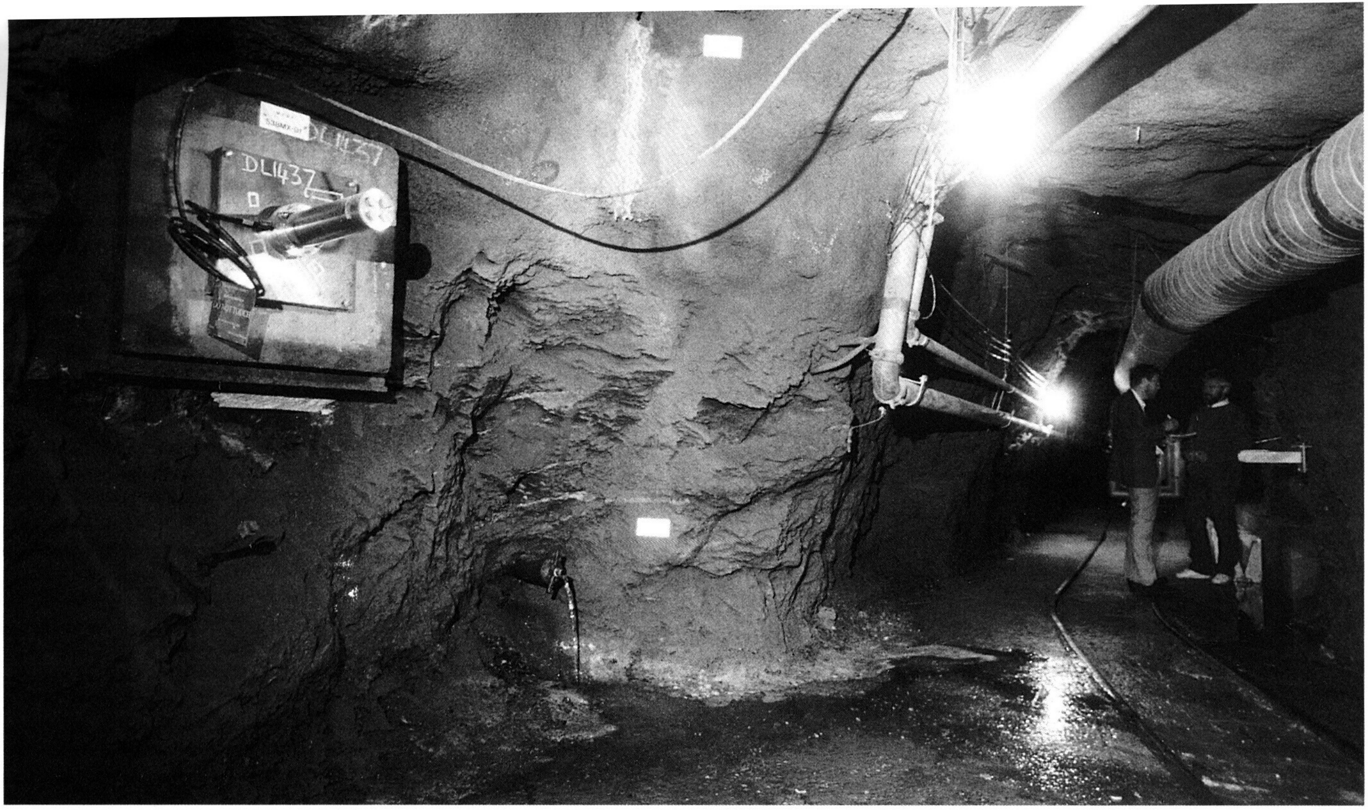
Generation and increased efficiency

The brief for the new corporation was to improve its performance and efficiency so that the maximum amount of electricity could reliably be generated and transmitted at the minimum cost from the existing system, and to prepare the way for a competitive market in electricity generation and supply. In order to introduce market signals into the operation of power stations, from 1988 the corporation operated an internal 'spot market' as a basis for establishing stations as profit centres with market incentives, together with an external week-ahead market providing limited scope (up to 10 per cent of customers' annual requirements) for variations from contract quantities.

After Clyde, no further power stations were built for a number of years. The corporation's Establishment Board had advised the government that there was no need to make a start on the Luggate project on the upper Clutha — which was being put forward principally by the Ministry of Works and Development on the grounds of retaining both engineering expertise and a construction workforce — and the project did not go ahead. Over the next few years the corporation also investigated possibilities in the lower Waitaki River and in the Mohaka River, as well as considering the conversion of Meremere to combined-cycle generation, but the increased efficiency of existing stations meant that ECNZ was able to keep putting off a commitment to new projects.

But although no new stations were built, Clyde and Ohaaki were completed, the Cook Strait cable was upgraded, and the efficiency of hydro stations was dramatically improved. (The story of Ohaaki is told in Chapter Thirteen.) This success in improving productivity and efficiency that made it a world leader in generation was to be one of ECNZ's major arguments against being broken up.

ECNZ was initially unenthusiastic about both Clyde and the Cook Strait cable upgrade. For a time shortly after corporatisation the decision to continue with the construction of the dam was poised on a knife-edge; economically, the advantage in doing so was very slight even then. Deane went so far as to say later that had ECNZ been starting afresh and with knowledge of all the geological problems at Clyde, it would have scrapped the proposal. Approval of the cable upgrade involved the rejection of another option, expanding thermal capacity in the North Island.



A number of tunnels had to be bored into the sides of the Cromwell gorge in order to reduce groundwater pressure through drainage. This tunnel inside the No. 5 Creek landslide was known as 'the Rathole'. The device at left monitors movement within the slide. At centre water flows from one of the many drainage points.
Evening Post, 20 January 1993.

Much of the construction phase of the Clyde project has been described in Chapter Fourteen. In 1990, after the completion of the dam the previous year, ECNZ formed a project team for Clyde to complete stabilisation work and commission the station. It was gradually realised that the sides of what was to be Lake Dunstan were unstable because of twelve ancient slides. In the end much additional complex and expensive work was required, costing $423 million and stretching to 1992. Works Corporation, to the horror of ECNZ, kept raising its estimate of the amount and cost of the work required as the full extent of the problem was uncovered. This additional work was the subject of some tough bargaining by ECNZ, which had with foresight covered such contingencies in the 1988 sale and purchase agreement with the Crown. ECNZ therefore received a compensation payment of $340 million from the Crown.

The stabilisation work involved buttressing and drainage to limit movement when the filled lake increased the hydraulic loading of the gorge sides. The buttressing entailed compacting five million cubic metres of rock and gravel at the base of slides to increase the weight and strength of their toes. Tunnels with a total length of 14.5 kilometres were driven into the slides for drainage to reduce groundwater pressure. Many drainage holes (138 kilometres in length) were bored both from within the tunnels and directly into the face of the gorge.

In April 1992 the filling of the lake began, overseen by an international review panel. Because of the potential instability, it was undertaken extremely cautiously in four stages, during which a specified level was held for some time. The installation of monitoring instruments to measure movement and deformation of slides and groundwater pressures was a vital part of the process. About 3,500 points on the dam and slides were monitored.

In late May the first unit was commissioned, with 65 MW generated to help counteract the drought of that year. Early in June another unit was commissioned, and Clyde began generating at full capacity for the first time in October 1992. The second, critical stage of filling was carried out more slowly on advice from the panel, and the third and then the final stages of filling did not take place until 1993, following close monitoring of a slide that began to accelerate for a time. Lake Dunstan finally reached its maximum height in October 1993, and the station was officially opened in April 1994 by Prime Minister Jim Bolger. New Zealand's largest concrete gravity dam had also been one of its most controversial, its construction plagued by argument, industrial disputes, geological problems and cost overruns.

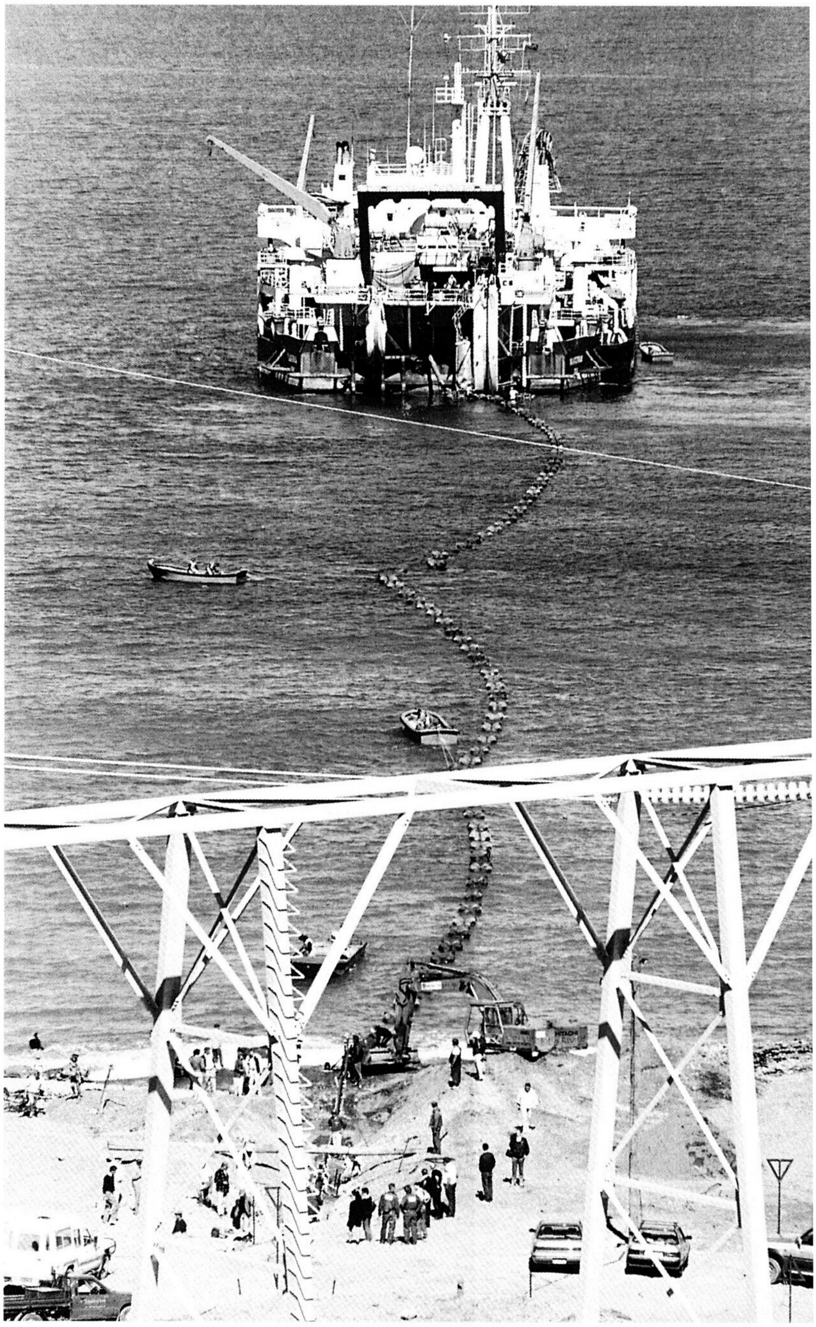
The general feeling was that there was not much to celebrate.

The upgrading of the Cook Strait cable proceeded very differently — it was rapidly approved, the cables were laid and the project was completed on time and within budget (see the description of the project in Chapter Eight). ECNZ had begun investigating the possibility in 1987, in anticipation of Clyde being commissioned, and after extensive analysis of options, a hybrid link which would build on the existing cables and use increased current and higher voltages was decided upon.

The project, which was the corporation's largest investment — costing $589 million and financed from borrowing — was approved in February 1989. A Norwegian consortium (ABB and STK–Alcatel) would manufacture and lay the three new cables, while the Swedish firm ASEA Brown Boveri would upgrade the converter stations. This would result in an expansion of the link from 600 MW (northwards) to 1,240 MW.

Three power cables and two smaller fibre optic cables, each 39 kilometres long, were laid in early 1991. While the *Skagerrak* stood offshore from Fighting Bay in the South Island, each cable was floated off on air bags and hauled to land by wire. The air bags were removed and the cable guided to the sea floor by divers. The ship then moved across Cook Strait paying out the cable, which was monitored by remote-operated cameras as it sank. On reaching the North Island at Oteranga Bay, the *Skagerrak* stood offshore and sufficient cable was paid out to reach the terminal. The cable was then cut and hauled onshore supported by air bags. When bad weather struck one cable had to be capped and dropped into Cook Strait, to be successfully located and retrieved later.

Laying went well and testing began late that year. New solid-state converter equipment was installed, the existing mercury-arc valves were reconfigured, and the AC switchyards at the Benmore and Haywards substations were extended. The 600-kilometre-long DC transmission line was strengthened, with this work using live-line techniques on high-voltage DC for the first time. Subsequent events demonstrated that ECNZ had acted just in time, as two of the three old cables failed over the summer and were subsequently written off. Bob Thomson, the Chief Executive of Trans Power, heaved a sigh of relief. 'We are just bloody lucky to have the new ones in and running ... Come winter time, with only 300 megawatts going north [in the third old cable], we would have been looking very sick'.[8]



The last Cook Strait cable is brought ashore from the Norwegian cable-laying ship *Skagerrak* in Oteranga Bay. The *Skagerrak* successfully laid three cables – each 39 kilometres long – in what were described as the strongest currents the ship had ever experienced.

Dominion, 11 March 1991.

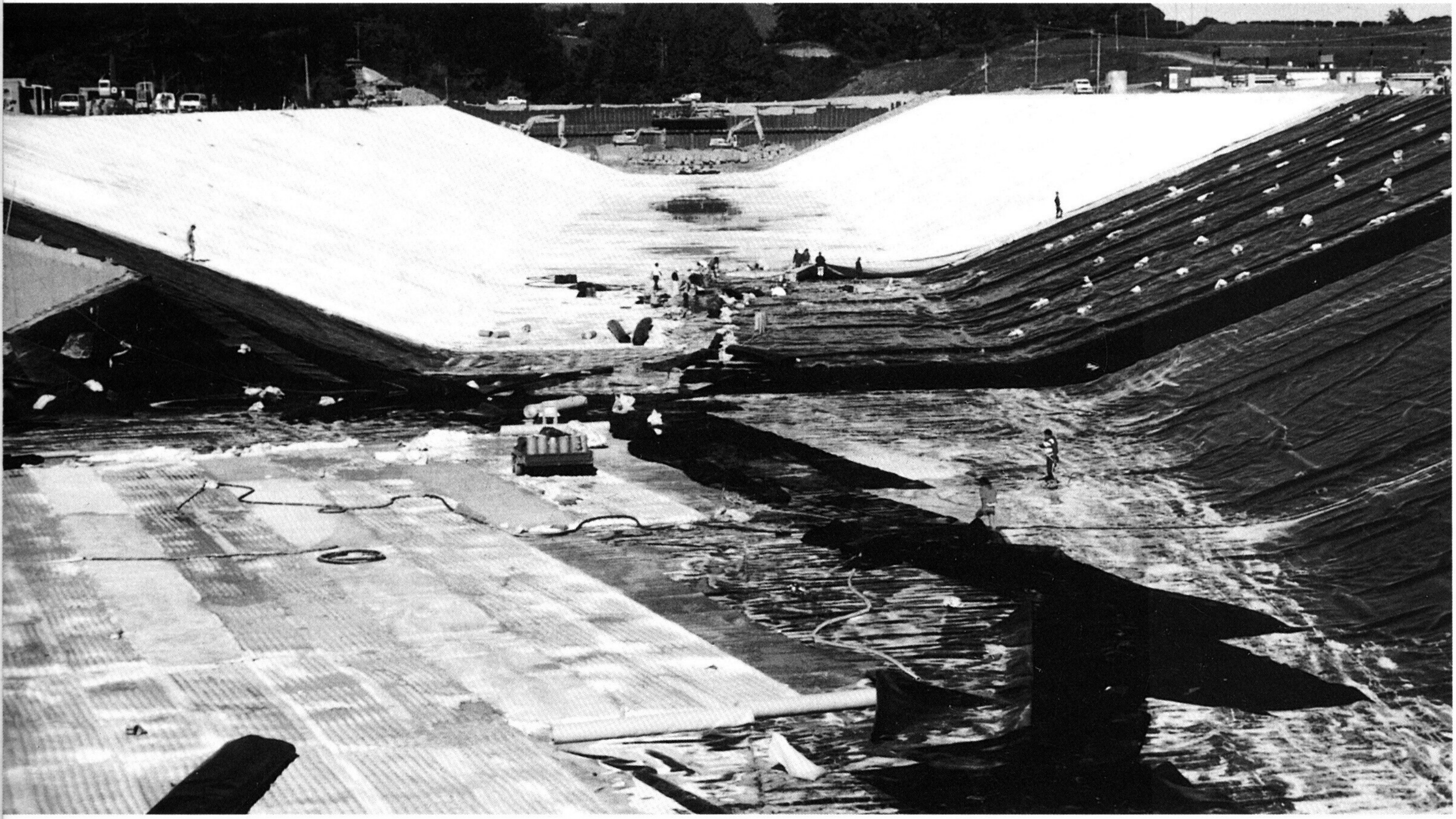
The extent of the corporation's good fortune was fully revealed during the winter of 1992, when the link proved crucial in conserving hydro storage in the South Island. In June it was supplying up to 40 per cent of the island's needs from the north. The following year large amounts of power were sent north as South Island lake inflows were high. An additional advantage for the future was the strengthening of the North and South Islands into a single market. The upgraded link was officially opened in March 1993 by Maurice McTigue, the Minister for State Owned Enterprises. At the end of 1996 the last of the old cables had to be decommissioned, reducing the rating of the link to 1,080 MW.

ECNZ was concerned to ensure that the link was effectively protected from damage. Underwater cameras used to investigate gas leakages from the old cables had revealed anchors and fishing gear fouled in the cables. Trans Power subsequently embarked on a thorough underwater survey of the cables. A concerted campaign resulted in new tougher legislation in 1996 providing for a cable exclusion zone, fines of up to $250,000, the confiscation of vessels or equipment, and extended enforcement powers. Trans Power began to mount a substantial surveillance operation by patrol boat and helicopter, but was unable to prevent the dragging and breaking of one of the fibre optic cables in November 1998. The break, twelve kilometres south of Oteranga Bay and at a depth of 200 metres, is likely to cost several million dollars.

ECNZ also made strong efforts to squeeze more power out of existing stations, improve the co-ordination of resources and reduce staffing costs by automation and remote control.

After a review commenced in the early 1980s and the subsequent rejection of the option of building a new station, the old Waikato station of Arapuni, originally commissioned in 1929, was comprehensively refurbished between 1984 and 1990 at a cost of $38 million.

The old diversion tunnel was brought into service as a new spillway to deal with floods and to bypass the station during its refurbishment. From October 1989 to May 1990 Arapuni was bypassed, the historically troublesome headrace



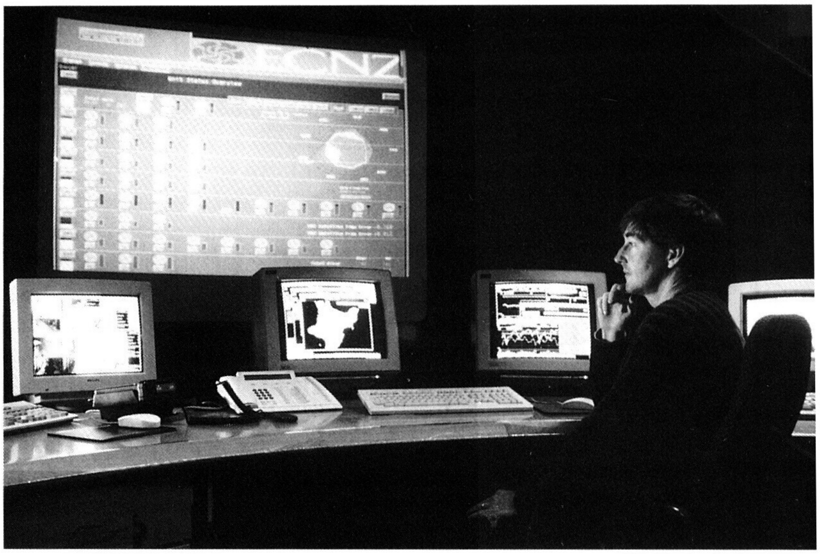
A key part of the refurbishment of Arapuni was the enlarging and relining of the headrace. Leakage through the headrace had caused serious problems when the station was commissioned and it had to be shut down in 1930 while a flexible watertight lining was installed (see pp. 94–7). The lining continued to cause concern during the station's operation. Here the difficult task of replacing the lining (with high-density plastic sheeting overlaid with a concrete mattress) is being undertaken, April 1990. A sense of the scale is given by the two tiny figures on the headrace slopes. Wayne Richards, ECNZ Northern Generation Group.

(see Chapter Four) was enlarged and relined, the tailrace excavated, and the powerhouse comprehensively refurbished. This involved the provision of new turbine runners for four machines, new control systems for all eight units and a new control room (resituated in ten days!) to replace the old narrow one that lacked natural light, had no view of the machine hall, and contained bare conductor busses and bulk oil circuit-breakers. An additional gain as a result of the work was an increased capacity to deal with floods that allowed the raising of the operating levels of other Waikato dams to their original designed levels; 32 GWh per annum was recovered in the process.

Although the project was undertaken at a time of sensitive industrial relations and the shutdown had to be as brief as possible, there were no difficulties and the project was completed on schedule. At the time of writing the other four turbine runners are being replaced, as are the stators and transformers for all units, which together with the earlier work will result in an 18 per cent increase in Arapuni's capacity from 158 to 186 MW.

At the end of 1989 ECNZ announced plans to automate and remote-control fifteen North Island hydro stations. This proposal had been under consideration for some years, having been advanced by the 1986 task force and recommended by the 1987 Establishment Board. The four-year project, which cost about $40 million, was completed well ahead of schedule and under budget, although outages increased for a time as teething problems were experienced, and staff reductions were not as great as had been anticipated. The project began with the automation of Matahina, which was completed by the end of 1991. (In the same year Ohaaki was controlled from Wairakei and Stratford from New Plymouth.) This was followed by work on the Lake Taupo control gates, Karapiro, Waipapa and Maraetai in 1992, and Arapuni, Ohakuri, Whakamaru, Aratiatia and Atiamuri in 1993. In the latter year the three Waikaremoana stations were also automated. In the first half of 1994 all the Waikato stations and Matahina were linked into a remote-control system based in Hamilton. The expected increase from automation was about 88 GWh per annum, but the gain has proved higher than this at well over 100 GWh.

Computer systems were installed in each station. ECNZ assisted the American manufacturers of the SCADA (Supervisory Control and Data Acquisition) system to improve it to meet required specifications. When SCADA was installed, what had been a slow process involving operators moving around the station manually controlling equipment became a sensitive monitoring system which allowed them remotely to run stations much closer to their optimum levels. As project manager Neil Simmonds explained, 'before, when we relied on the experience of our operators, we couldn't run the stations as close to the limit in case we breached resource consents. Now the data is so accurate that we can optimise every generator in every station.'[9] Another advantage was the immediate detection of problems such as excessive vibration in shafts before they had catastrophic results. ECNZ opened visitor centres and organised open days to enable continued public access to stations without staff.



Richard Smith, operator, monitors stations on the Waikato River at the Northern Generation Control Centre.

An integral part of the plan was the shifting of the North Island control centre from Whakamaru to Hamilton. Following the automation work each station required only one operator/maintenance worker during the day, while at night the entire chain was controlled by two operators in Hamilton. This centre also provides the overall scheduling of ECNZ's generation throughout the country. The previous staff of 150 for the stations was cut back to 40, with an additional 18 operators and other staff in Hamilton.

While originally intended to be part of the same system, the Tongariro stations and various structures were in the end controlled remotely from Tokaanu because of the separation of the

North Island Hydro Group into two competing groups. The Tokaanu centre used a replacement SCADA system and also gathered data on the operations of Mangahao (until it was sold) and the Waikaremoana stations. The automation of the North Island hydro stations resulted in considerable gains in efficiency and energy produced.

By the early 1990s ECNZ had made substantial progress in transforming its operations. Since 1987 staffing levels had nearly been halved, fuel costs had been halved and productivity had increased by nearly three-quarters. Operating unit costs had fallen by 15 per cent and the average wholesale price of electricity had fallen by 21 per cent, both in real terms (see Appendix 4). The corporation through its improvements to stations had made an effective capacity gain equivalent to a substantial power station. Such gains went largely unappreciated by the public, unfortunately, and when continued uninterrupted supply was threatened by drought they counted for little.

Drought and redirection

The power crisis of 1992 resulted in a loss of public confidence in ECNZ. The negative publicity that had plagued the corporation from its inception came to a head during this 'winter of discontent'. The corporation came to realise that it would have to shift its strategic direction to rebuild its public image and promote energy efficiency.

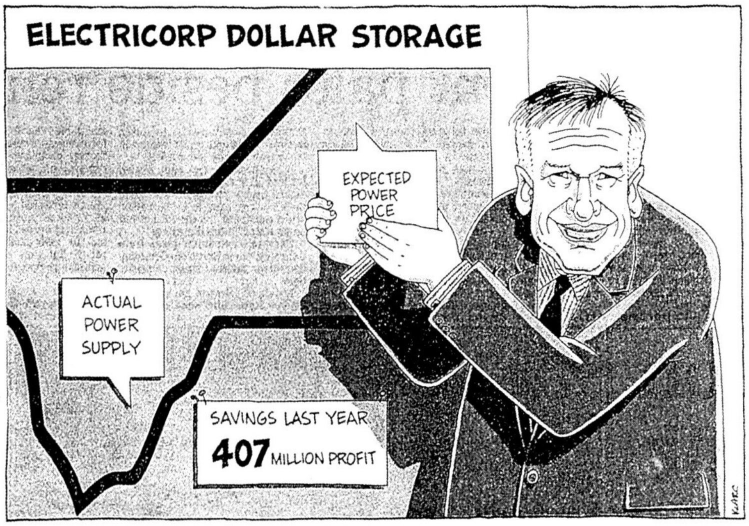
A warning of what was to come occurred the previous winter when extremely low South Island lake levels were experienced and Manapouri had to be shut down temporarily. Huntly had to be run on overload, Marsden A was run flat out, the Comalco aluminium smelter was forced to reduce its load, and power was sent to the South Island at night via the cable to conserve lake levels.

From November 1991 South Island lake inflows were very low. By April 1992 they were 40 per cent below normal, at a time of year when they are usually close to their maximum levels. The lowest inflows on record were experienced in May and June, the very period when much of the lake replenishing usually occurs. The overall effect of the drought statistically was a 1 year in 100 year event.

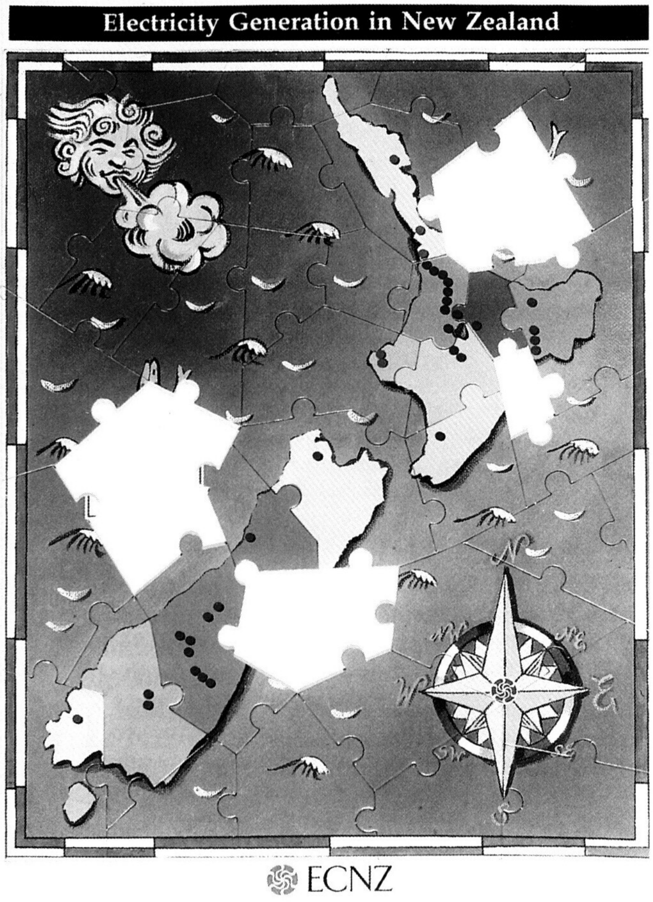
By late March South Island lakes were actively being conserved, assisted by Huntly and New Plymouth.[10] In early May ECNZ began sending power south at night as the drought began to bite. On 6 May it issued a press release outlining the situation and indicating that there might be difficulties in meeting demand. Then Stratford and Otahuhu were pressed into service, followed by Marsden A, which had been recommissioned. The commissioning of one unit at Clyde in late May (followed by another in early June) helped but the situation steadily worsened. In early June an Electricity Industry Committee was formed to act as a co-ordinating agency during the crisis. It agreed upon the need for 10 per cent savings; the Electricity Supply Association asked its members for voluntary savings, and cuts to water heating and street lighting were made. The Comalco smelter, which took more than 40 per cent of the South Island's energy, was of particular importance. Following intensive discussions, Comalco agreed to close one of its three potlines.

By July the Electricity Industry Committee asked for savings of at least 15 per cent, and an energy efficiency campaign was launched. However, heavy rain in the South Island in late July brought relief and enabled a relaxation of savings targets. At the end of the month Comalco was notified that the potline could be restarted and the savings targets were called off.

The power crisis resulted in a government inquiry that cleared ECNZ in concluding: 'the primary cause of the shortage was the prolonged drought ... and in particular the extremely low inflows to the hydro storage lakes ... exacerbated by an unexpected increase in demand.'[11] The Electricity Shortage Review Committee found



The popular perception of ECNZ during the power shortage in the winter of 1992.
New Zealand Herald, 31 July 1992.


Electricity Generation in New Zealand
ECNZ

This jigsaw puzzle advertisement in newspapers following the power shortage portrayed the interlocking nature of New Zealand's generating system.

'no evidence to support allegations that ECNZ was derelict in its duties or deliberately mismanaged the system'. To the surprise of many it gave ECNZ a strong vote of confidence, dismissing a variety of rather extraordinary claims made by critics. However, the committee did note a few minor criticisms. ECNZ should have withdrawn advertising and encouraged voluntary savings earlier. Shortcomings in the timing of the start-up of thermal stations had also contributed to the severity and duration of the shortage.

The inquiry made it clear that the public had little understanding of the 1 year in 20 year security standard that had been adopted in 1979 and was used by ECNZ. The corporation decided voluntarily to move to a stricter 1 year in 60 year standard, that was more feasible with fuel prices lower than they had been in the 1970s, and took it upon itself to explain to the public how the electricity system worked.

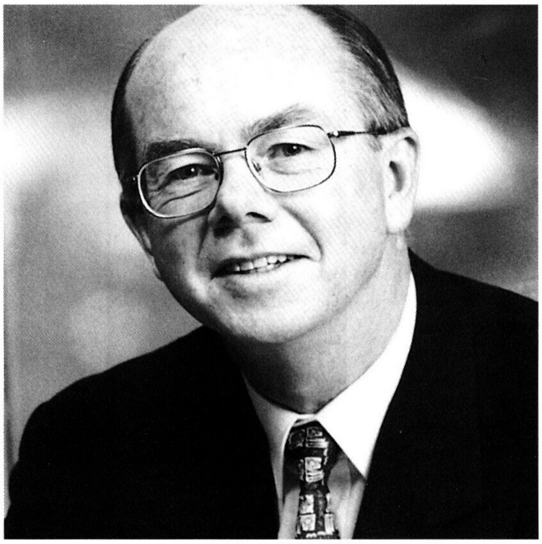
The power crisis, in spite of the findings, had a major impact on confidence in ECNZ. The news media tended to blame the corporation for the crisis; this came on top of the miscalculation of public perceptions of a proposed price increase in 1991 and the large profit announced in 1992. Morale inside the organisation declined and staff resigned, especially from Electricorp Marketing.

From mid-1991 ECNZ had begun to re-evaluate its strategic approach. Marketing was redefined, particularly for industry, not as simply selling electricity but by associating the product with highly efficient technology, and its more efficient use based on a renewable resource. This was aligned with a power merchant concept through which ECNZ hoped to become involved in the retail sector.

The public's perception of the company was increasingly acknowledged as a vital ingredient in the political environment. The corporation found it difficult to shake off an image of high cost and increasing prices, despite the real efficiency gains. The public struggled to come to terms with the transformation of electricity into a marketable product. The company concluded that it was in a trap created by its pursuit of commercial objectives in the context of a perceived absence of market constraints. This was encapsulated in the term 'monopoly' and was a fertile breeding ground for criticism, mistrust, misunderstanding and damage to its credibility. Anything that ECNZ did merely reinforced existing negative perceptions.

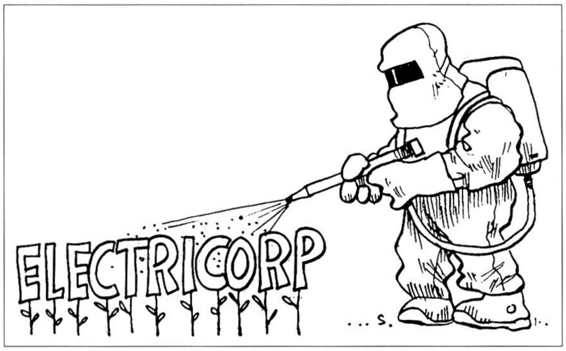
ECNZ determined that it should redefine its purpose, accept certain constraints on its commercial objectives, develop a less aggressive, more co-operative and collaborative approach, and adopt goals of customer service and energy efficiency. This reshaped strategy was accompanied by an internal reorganisation prompted by the Genco report, which suggested that the company's core business was in the generation and sale of electricity.[12] The Marketing, Production and Corporate groups were co-ordinated better and the sometimes disruptive internal competition was eliminated. Generation was reorganised by the establishment of seven generating groups, so that any future privatisation of some of ECNZ's generating capacity would be facilitated by the separate groups. As a result of improved station management and staff reductions, a layer of management in Production was removed.

It was decided to drop the public usage of 'Electricorp' — a name with which ECNZ



David (Dave) John Frow was born in Durban, South Africa on 16 July 1949. He was educated at Westville Boys' High School, Durban. He was awarded a BSc Eng in mechanical engineering in 1972 from the University of Natal and a Confederation of British Industry Scholarship for work study in the UK in 1974–75 with turbine manufacturer NEI Parsons Ltd and boiler manufacturer Babcock and Wilcox Ltd. He completed an Advanced Management Programme at Harvard University in 1990. Frow is a Fellow of the Institution of Professional Engineers of New Zealand. In 1996 he was elected to the Executive Council of the Association of the Electricity Supply Industry of East Asia and the Western Pacific. In 1997 he was elected President of the Harvard Business School Association of New Zealand. Frow has extensive engineering and managerial experience in the electricity industry in South Africa, where he worked for the Electricity Supply Commission commissioning and operating very large thermal power stations. After joining the Electricity Division in 1979, he became Station Manager at Huntly in 1985. Frow was on the Establishment Board task force of 1986–87 and became General Manager (Production) on the formation of ECNZ. He was appointed Chief Executive of ECNZ in November 1992. He was a Director of Trans Power, 1988–92, and its Chairman, 1992–94, and Chairman of PowerMark, 1992–96, and DesignPower, 1992–98. Frow has been at the centre of the reforms to the electricity industry since their inception, contributing greatly to making ECNZ a world-class generating company and steering it through the complex and difficult reform process.

had been saddled — and use the initials of its official name. The corporation felt that the suffix 'corp' was too closely associated with the fast-money 'corps' that had come to an ignominious end in the late 1980s. Unfortunately the drought intervened and it was decided not to push the change at that time because of fears of an uproar. Later, in March 1993, the company made the move and exhorted its own staff to 'treat the name Electricorp like the noxious weed Old Man's Beard. Stop and root it out wherever you see it.'[13]



The name 'Electricorp' is sprayed with weedkiller. *Connections*, no. 19, December 1993.

Fernyhough articulated the corporation's new thinking at the Electricity Supply Association's annual conference in September 1992. It would take a responsible attitude to planning for stations and was prepared to work with the government to promote more competition. It would also co-operate with cogeneration proposals. ECNZ, which had been contemplating building a new combined-cycle gas station in Taranaki but sensed the difficulty of going ahead with the project, suggested that it could sell part of its gas entitlement to another company wanting to build the station. The corporation gave a conciliatory assurance that it would not seek a price increase above the rate of inflation in the next round. Nor would it seek any retail involvement during the current reform process, something it desired strongly and had explored persistently.

Deane found it increasingly frustrating that privatisation was blocked, and he resigned suddenly in early October 1992 to head Telecom, following some attractive job offers and having set himself a period of five years at the helm when he joined ECNZ. Dave Frow, the General Manager (Production), was rapidly appointed to replace him with a brief to restore public confidence in the corporation.

Fernyhough's term as chairman was due to expire in February 1993, but he was persuaded by the government to stay on for another six months to oversee the splitting off of Trans Power. In an emotional announcement of his retirement, he described his sense of impotence at being unable to get his message across during the power crisis no matter what he said or did.[14] While he had been spectacularly successful in his mission to transform ECNZ into a profitable SOE, Fernyhough had been frustrated at being unable to privatise it, and this was a major reason for him quitting. In his final annual report he attacked the government for meddling in the corporation's business, in particular with respect to pricing and the failure to privatise. Selwyn Cushing replaced Fernyhough as Chairman of the Board of Directors.

Frow acknowledged that public confidence in ECNZ would take years to recover. His key objective in refashioning the corporation was to develop stronger relationships with customers who had become alienated. The more active approach to marketing and presenting the face of the corporation that had been such a culture shock to the power companies was softened. Emphasis was increasingly placed on improving the organisation's culture. A 'challenge' to staff in late 1993 spelled out ECNZ's mission as 'A World Class Energy Provider'. This mission emphasised customer service, improved performance, value for its shareholders, the environment, good working conditions for employees, and integrity. 'Benchmarking' for measuring improvement was introduced, so that comparisons could be made both internally and with other world-class companies. Improved performance management processes were introduced for all staff, and emphasis was placed upon a team-based culture and flexible training and development. More deliberate and co-ordinated planning was undertaken within the organisation through the creation of 'cross-functional teams', and a more consultative and co-operative style was fostered externally, particularly with the power companies, building on the foundation provided by the Electricity Industry Committee.

ECNZ also reviewed its public relations and identified issues management as a key weakness.

Selwyn John Cushing, the son of the manager of the Whakatu freezing works, was born in Hastings on 1 September 1936. He was educated at Hastings Boys' High School, studying accountancy extramurally. At age sixteen he joined the Hastings accounting and sharebroking firm of Corbin Esam and Co., later becoming a partner in the firm as Esam Cushing and Co. He qualified as a chartered accountant at the young age of nineteen before winning the 'best student in New Zealand' award in cost and management accounting in 1957. Cushing represented Hawkes Bay at cricket for fifteen years. He became a non-executive Director at Brierley Investments Ltd in 1974, while continuing to practise as a chartered accountant in Hastings, and became Executive Director of Brierley's in the period 1987 to 1993 and Chairman or Deputy Chairman of a number of associated companies. He was made a Fellow Chartered Accountant in 1990. Appointed Chairman of ECNZ's Board of Directors in 1993, he also chairs Brierley Investments Ltd, Air New Zealand Ltd, Viking Pacific Holdings Ltd, NZ Rural Properties Ltd and the New Zealand Symphony Orchestra Ltd. In addition he is a Director of the Bank of New Zealand Ltd, St Lukes Group Ltd and Williams & Kettle Ltd. He was awarded a CMG in 1994 for services to business management. Cushing has guided ECNZ through the reform process as it has unfolded, consistently advancing the interests of the corporation.

The corporation resolved to plan its public relations work more carefully, including the monitoring of its image in the public mind.[15] Initial work suggested that its role was largely taken for granted until problems arose and that its image was one of arrogance and secretiveness. Work over the following years succeeded in lifting levels of awareness of the ECNZ name substantially and improving perceptions of the corporation's ability to maintain continuity of supply and to provide electricity efficiently and cheaply. But there was continued polarisation of opinion on whether ECNZ was doing a good job in balancing making profits with managing resources efficiently.

The corporation strengthened its emphasis on energy efficiency in its marketing and developed initiatives in association with power companies, to which it had moved closer after the 1992 power shortage. It also supported the formation of the Energy Efficiency and Conservation Authority in October 1992 as a suitable vehicle for the public interest in energy efficiency, and in the recognition that its objectives and its lack of an effective relationship with end-users of electricity limited its own contribution in this area.

The Medallion Award scheme, recognising energy-efficient all-electric homes, had been introduced in mid-1990 and had resulted in more than a thousand homes receiving awards. This was followed by the formation of an Energy Services Group and the development in 1993 of the HERO (Home Energy Rating Options) programme, which provided assessments of and advice on improving domestic energy efficiency. This scheme was franchised to a number of power companies and ran until 1995. This approach to domestic consumers was complemented by the provision of energy services to power companies in order to retain industrial and commercial customers, involving energy audits, advice and access to information.

In August 1994 the 'spinning plates' advertising campaign was used to illustrate the many different, conflicting needs — economic, technological, environmental and consumer — that ECNZ had to balance, and to express the reasserted sense of unity and purpose that followed the Genco report. During the production of the clip a woman previously capable of spinning 10 plates simultaneously was able to get up to a total of 23 plates with the assistance of the film crew (only 6 were broken — apparently by the crew). The footage was then computer-enhanced to triple the number of plates apparently in motion. The same advertisement was used later that year to shift the message towards the corporation's energy efficiency and environmental responsiveness.

In 1995 the corporation launched the 'It's Electric' campaign in recognition of both the competition provided by other energy sources such as gas and the approaching competitive wholesale market. This campaign involved promoting electricity as the preferred source of energy and ECNZ as the preferred supplier able to add value to the product. ECNZ participated in co-branding with power company sales of appliances. The goal was to underline the attributes of electricity through images of excitement, energy and colour. The campaign was begun by articulating the values of electricity through the eyes of children, in order to convey a sense of wonder about an everyday, taken-for-granted product in an entertaining fashion.

With it becoming apparent in 1995 that some kind of split of ECNZ would occur, the corporation took the opportunity to rethink its role.[16] Consultants confirmed that by international standards its stations operated extremely efficiently and at low cost. Its wholesale prices also remained very low. The corporation's objectives were recast towards marketing itself as a preferred supplier and providing a high-quality service to customers, while keeping base-load prices low to make it difficult for competitors to enter generation.

Consultants argued that the 1992 reorganisation — while it had improved co-operation and co-ordination, removed some duplication, and dismantled some outmoded mechanisms — had been enforced from the top down and had not necessarily 'won hearts and minds'. It had not entirely overcome conflicts between the formerly separate profit centres, and the role of marketing was still unclear. The consultants emphasised the importance of avoiding what they called the 'doom loop' of declining market share and profit as new entrants with 'embedded' capacity (in proximity to the demand and not using the grid) and captive markets displaced ECNZ.

From late 1995 ECNZ was reorganised. Operating divisions were 'pruned back to their core business', strategy and business analysis were grouped together, and a business development group was formed. The Chief Executive was now supported by an executive board of general managers.

ECNZ grappled with the constraints that were likely to be imposed on it with a split and the creation of a new SOE following the industry reform report of 1994 (see Chapter Sixteen). It decided to continue with low-cost generation; not to divest itself of capacity (such as Huntly) in order to maintain its mix of generation; to be more assertive commercially; to raise the value of its core product; and to invest in new generation, and in fuels and energy retailing in order to become a market leader. This became the corporation's vision.

Following the splitting off of Contact Energy, ECNZ revalued its assets upwards to $3.275 billion. In the year to June 1996 it made a substantial profit and recorded its highest rate of return yet of 14.1 per cent — even though the wholesale price of electricity had fallen substantially in real terms over the year. Clearly the corporation was continuing to perform well, even if the future remained uncertain.

As a measure of confidence in its performance, in early 1996 the 'Electricity — Believe In It' campaign was launched. In this campaign advanced electrotechnologies for the home (such as heat pumps and induction cooking) and the energy efficiency of electricity were 'uncovered' by the actor who plays Agent Scully from '*The X Files*'. Because of increased competition introduced with the establishment of Contact Energy the focus of marketing then shifted towards commercial contracts. With ECNZ's very recent entry into retailing in late 1998 through its subsidiary First Electric, marketing has emphasised lower retail prices and the ease of transferring to a new company in order to entice customers away from other energy companies.

ECNZ and the environment

A key aspect of forging a better relationship with the public was ECNZ's approach to environmental issues. As its 1998 environmental report puts it, the corporation 'aims to be a trusted user of ... natural resources and a respected member of the community'.[17] The corporation realised at an early date that this approach was a key to gaining greater trust and respect from the public, particularly as it would soon have to renew hundreds of resource consents and thus risked the loss of significant electricity generation. A condition put on the corporation on its formation was the renewal of all its water rights within fifteen years. The passage of the Resource Management Act in 1991 required the renewal of all consents by 2001, two years sooner.

Key elements in ECNZ's approach are improving efficiency in the use of resources, favouring renewable resources when it is economic to do so, improving environmental management and using a consultative approach. The corporation also supports efficient energy use and is investigating new technologies which promise increased utilisation of renewable resources.

ECNZ had drawn important lessons from the Rangitikei–Wanganui Regional Water Board's setting of higher minimum flows for catchments of the Wanganui River in 1988, during which the corporation had been forced into an adversarial and defensive role. Moreover, it felt that the national interest in generating electricity from a non-polluting renewable hydro resource was being overshadowed by local interests in both the Wanganui debate and the draft Resource Management Bill. It described the pressure to reduce access to water as the greatest single threat to the development of clean and efficient energy, predicting that more than 200 GWh would be lost and an extra 170,000 tonnes of CO_2 produced annually as a result of the Wanganui (and Waitaki) restrictions.

The diversion of water from the upper catchments of the Wanganui River since 1971 had been limited by a number of environmental constraints, the 'Shand' agreements, which set some minimum flows for the diverted rivers. These were intended to ensure a sufficient volume to operate a locally owned power station on the Wanganui River near Taumarunui, to protect the trout fishery in the Whakapapa River, and to keep water temperatures down to a desirable level.

Following pressure from canoeists the National Water and Soil Conservation Authority fixed higher flow levels in the 1970s, and these were renewed in the early 1980s. After a local campaign in 1988 the Regional Water Board decided to reduce the amount of water that could be taken out of the catchments considerably, by 32 per cent. ECNZ was determined to reduce the impact on its generating potential in line with its objectives of generating electricity efficiently and at least cost, and it appealed against the decision, arguing that 200 GWh per annum would be lost. After an exhaustive hearing, the Planning Tribunal found in 1990 that the corporation should reduce its abstraction by 19 per cent (a loss of 120 GWh), this being an appropriate readjustment of 'the interests of the nation and those of the region' on multiple-use criteria. ECNZ appealed against the finding to the High Court, but it affirmed the tribunal's decision in 1992. The Department of Conservation actively supported those arguing that more water should be left in the river.

The corporation's litigation produced a widespread antipathy towards it, reflected in newspaper comment such as the *Dominion*'s: 'once again, the [greedy] Electricorp behemoth is rampaging through the corporatised landscape'.[18] The resurfacing of the controversy during the drought of 1992 did not help the corporation's cause. As the *Manawatu Evening Standard* editorialised: 'quite simply, we've heard it all before ... [Electricorp has a] "profit at any cost" corporate mentality ... it does not have a licence to ignore social and environmental needs in its drive to grab a bigger slice of the natural resource cake'.[19]

In the end ECNZ decided to abandon continued court proceedings. Much damage was being done to its reputation. It decided to focus on the longer-term issue of gaining water rights under the Resource Management Act for all of its existing stations, including the entire Tongariro power development.

In the wake of the Wanganui episode ECNZ was determined to improve its reputation on environmental issues. It developed corporate environmental principles and continued its commitment to consult with local communities and to undertake joint investigative projects. In 1990 Matahina became the first station to gain renewed water rights. ECNZ devised an elver pass at Matahina to allow young eels upstream; this received an environmental award.

In 1991, after extensive consultations, the establishment of the Waitaki Working Group, and an environmental agreement taking into account Maori values, irrigation, fishery, wildlife habitat and recreational use, the Canterbury Regional Council granted new rights for the Waitaki stations. The resource consents were granted quickly and with little debate because the local community and interested groups had participated in the process and had agreed to the application to the Council.

Although the new consents reduced generation potential by 95 GWh annually, this was a great deal less than would have been lost had there been a requirement to restore flows in the rivers and delta that would have bypassed the stations. A compromise was reached with 'Project River Recovery', through which the habitat for rare wading birds was restored by human means rather than by increased flows. ECNZ and the Department of Conservation reached agreement on the restoration of braided river habitats — involving the clearance of willow and lupins and restoration of clean gravels — in the Ahuriri and Tekapo Rivers for the black stilt, wrybill and black-fronted tern; more than $3.2 million was spent in the succeeding years. The Regional Council gave the Working Group a resource management award in 1993 in recognition of its work. Other features to emerge from consultations were the provision of irrigation for farmland, the creation of an international-standard white-water canoeing course in the Tekapo River by the release of water from Lake Tekapo, the restoration of flows in the Ohau River in order to improve the fishery, and the construction of fish passes on the Benmore, Aviemore and Waitaki dams.

The process by which consents were gained for the Waitaki provided a lesson for the future. Mark France, Environmental Manager for the Southern Hydro Group, who 'could see the potential for major confrontation and costly court cases' and had listened to local concerns and assisted in the formation of a working party, observed that 'it was astonishing [to witness] the significant change in [local] aspirations' as a result of the consultations.[20] At the beginning of such processes the corporation would come under sustained attack as long-felt grievances were aired. Having got that out of the way, people were often much more ready to discuss in an open-minded fashion the options for dealing with the issues in the future, and common ground could usually be found from which all could benefit.

The secret was to avoid adopting entrenched defensive positions and be prepared to accommodate other interests and concerns. Sometimes novel alternative solutions could be found, such as that for the restoration of bird habitat in the Waitaki, or the funding by ECNZ of tourist publicity material for the town of Tekapo in response to dust storms that had swept the town when lake levels were low. By working through these issues with the people concerned ECNZ found that it could often achieve its goals at minimal cost while being responsive to the concerns of the communities involved.

In 1992, as part of this new approach, ECNZ formally committed itself to a set of environmental principles, in which it aimed to be a trusted user of natural resources and resolved to adopt a consultative approach and set high standards of environmental management. In the same year consultative working parties were

Patrick Robinson (Manager, South Island Hydro Group) left, Mark France (Environmental Manager, South Island Hydro Group) centre, and Dave Murray (Department of Conservation) discuss how to restore the Ahuriri River habitat.

established for Huntly, Mangahao, the Tongariro scheme and the Waiau catchment (Manapouri) in preparation for applications for renewed consents, and studies for air discharge applications for Huntly and New Plymouth were commenced.

Mangahao had its resource consents renewed in 1993 in association with the upgrading of the station. In 1994 the consent for Huntly to take Waikato River water for cooling purposes and discharge it back into the river was renewed after a lengthy $3 million public consultation process and studies of fish habitats. ECNZ installed 'hydroslides' to flush fish back into the river from the cooling intakes, and large numbers of other conditions were met. An air discharge permit proved difficult to renew. ECNZ wanted a long-term permit, but objectors were concerned at the two million tonnes of CO_2 produced annually, about 10 per cent of the national total. While ECNZ was given a twenty year permit in 1994, this was subject to reviews every five years or whenever international CO_2 obligations made it necessary.

For the Waikaremoana power scheme, a working party was formed and consultation with community and environmental groups took place from April 1995. Studies of the effect of lake levels, flows, water quality, fish habitat and migration, and eels were commissioned. ECNZ subsequently applied for resource consents for the scheme in April 1998. In its application the corporation proposed a regulated discharge regime for Lake Waikaremoana at its maximum operating level that would reduce the power scheme's annual output slightly. It also proposed a number of mitigation measures, including working with the Department of Conservation to enhance the local ecology, releases of water from Lake Whakamarino for recreational purposes, and assistance for the passage of eels and for the establishment of a fishery trust.

ECNZ's increasing environmental commitment was reflected in it being amongst the first group of companies to sign a voluntary agreement with the government in 1995 to reduce CO_2 emissions to within certain targets. It had already reduced its production of CO_2 considerably in the early 1990s by limiting the use of thermal plant.

The corporation's continued search for greater efficiency was consistent with reducing the use of thermal generation and lower production of CO_2. The construction of a second Manapouri tailrace tunnel, and the automation and remote control of both North Island and South Island hydro stations have contributed to achieving this goal.

In 1996 ECNZ began to publish an annual environmental report in order to indicate its 'commitment to being a responsible user of the country's natural resources' and to using a consultative approach.[21] After three years' work, the consents for the Lake Coleridge station were renewed that year.

Following a six-and-a-half-year consultation process, ECNZ — which had funded and worked with the Waiau Working Party set up by the Southland Regional Council — in 1996 was granted consents for the Manapouri power station for the next 35 years. These included the same lake operating guidelines, a modified management regime and the monitoring of the lakes and the Waiau River, fish passes, and new minimum flows for the lower Waiau River. The new consents incurred little loss of energy compared to the old regime. They required monitoring of both the quality of water discharged into Deep Cove and its impact on the marine environment in Doubtful Sound. This is now taking place.

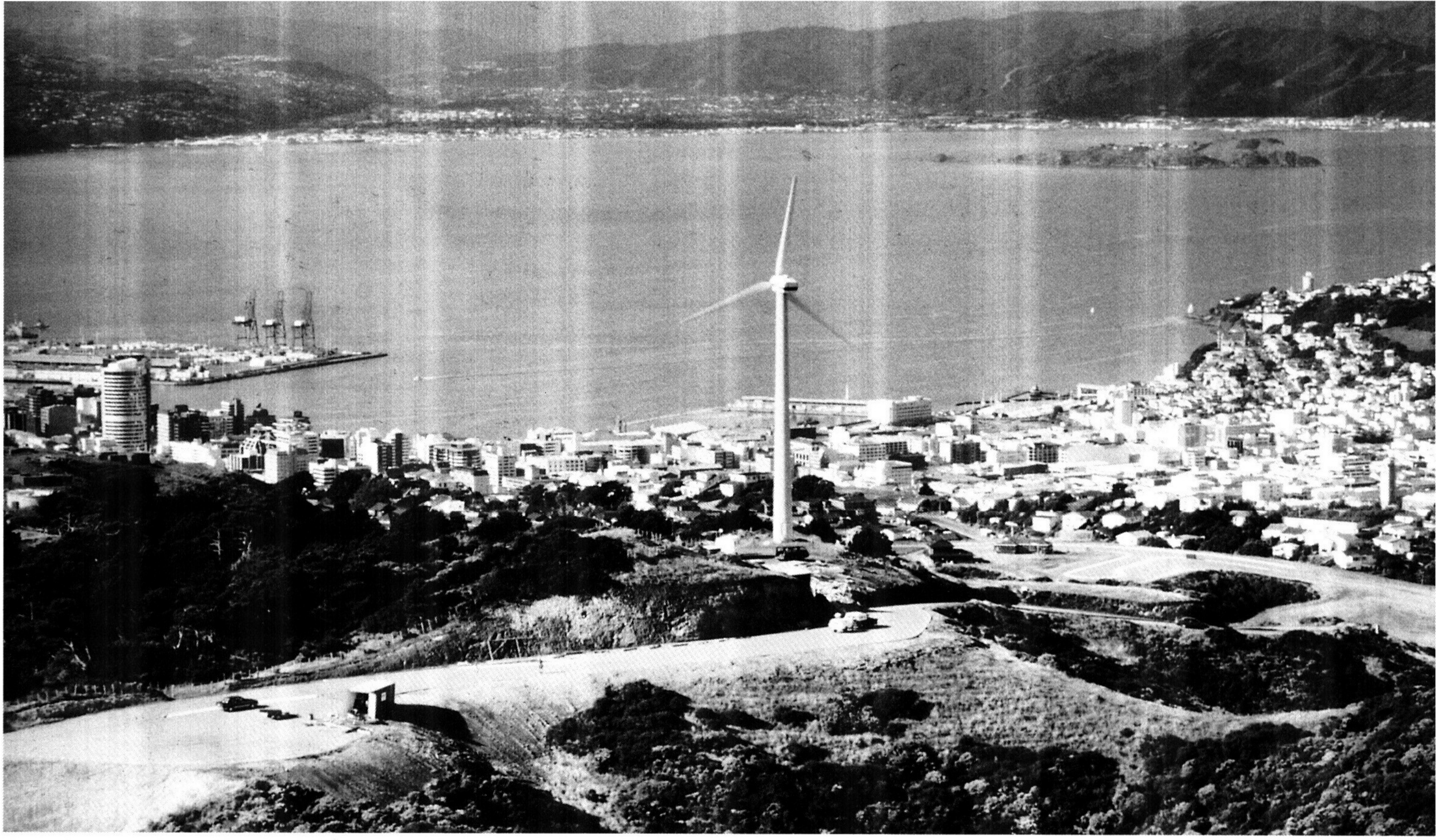
ECNZ established a number of trusts for fisheries and habitat and provided $7.5 million for measures to enhance and protect the lower Waiau River through the restoration of wildlife and fisheries habitat, wetland development, the provision of boat ramps and the provision of community amenities for Tuatapere. The lower Waiau River below the Mararoa weir, which had been virtually non-existent except in times of flood, was much enhanced by the new average minimum flow requirement of 14 cumecs and other flows provided that benefited many groups and improved the fishery markedly. ECNZ won an environmental award from the Regional Council for its consultative approach to the Manapouri consents. The corporation was proud of this achievement, particularly in view of the environmental controversy of the late 1960s.

In 1996 ECNZ also began consultations and investigations prior to seeking renewed consents for the eight Waikato hydro stations and the Taupo control gates. A large number of studies were commissioned on physical, cultural, ecological, dam safety and recreational issues. In 1995 a programme was established at the Karapiro dam to trap elvers and release them into a number of hydro lakes further up the Waikato hydro chain. The process for gaining the large number of Tongariro power development consents was commenced some years ago and is expected to be completed in early 2000.

A bucket of elvers (young eels), due for release into the Waikato hydro lakes, are displayed for the photographer. The elvers find their way upstream into four traps at the base of the Karapiro dam, the first barrier on the Waikato River, and then into holding tanks. The tanks are transported upstream to the hydro lakes and the elvers released.

Waikato Times copyright.

From 1997 ECNZ published a range of environmental indicators which enabled monitoring of its performance. The corporation has now renewed nearly three-quarters of the resource consents required for its power stations. Having once been seen as simply pursing a narrow profit motive, it is now regarded as a model to be



ECNZ's 225 kW wind turbine stands high above Wellington's suburbs and harbour.

emulated thanks to the measures it has taken to deal with environmental issues.

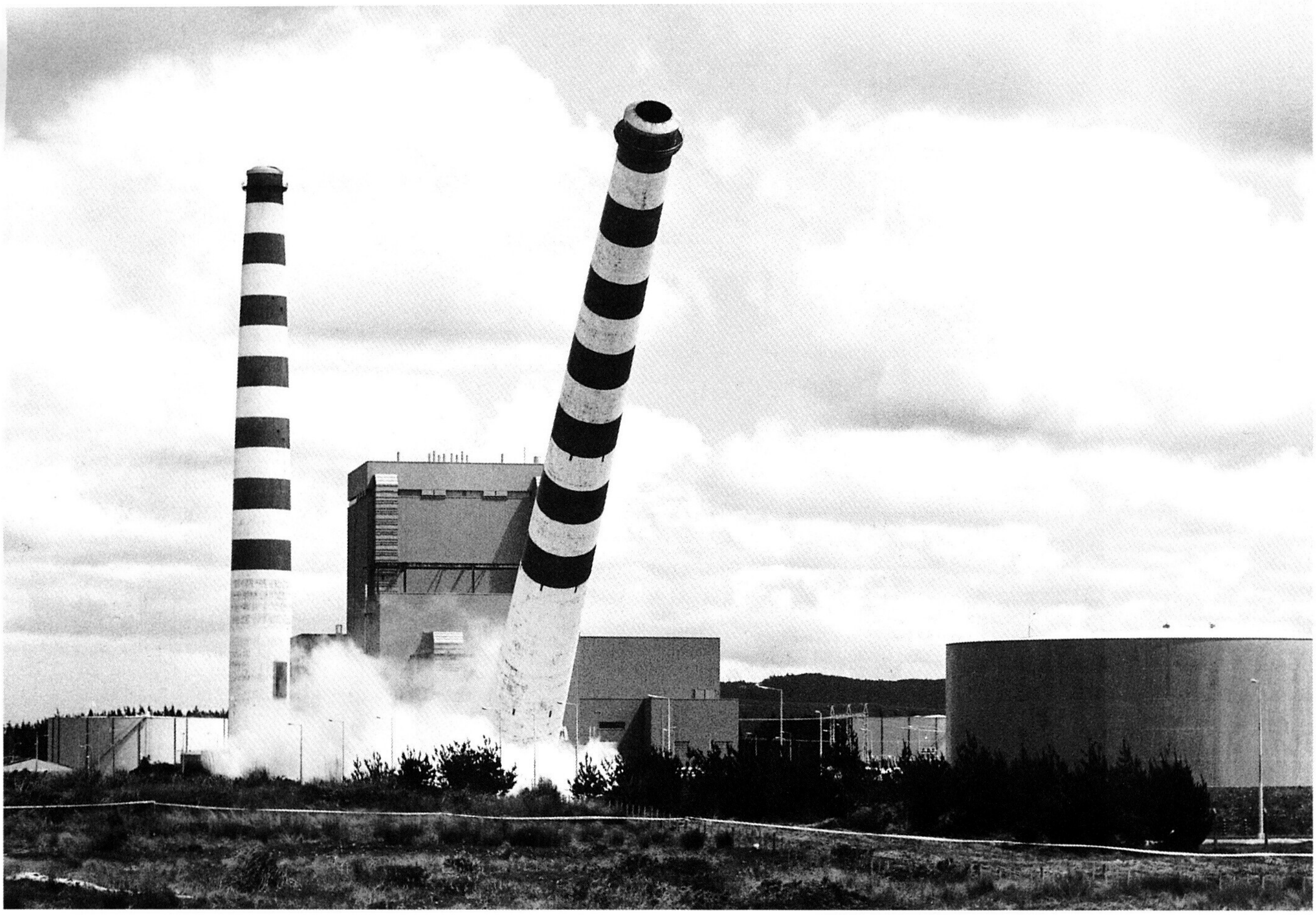
ECNZ began to investigate other forms of renewable energy from the early 1990s. In March 1993 it commissioned a 225 kW wind turbine, high on Hawkins Hill above Wellington, as a visible statement of the potential of windpower, which was then approaching the margin of being commercially viable. This was followed by investigations into developing a wind farm of 30–40 MW involving between 50 and 80 turbines (depending on size) on an exposed site at Quartz Hill, Makara, after the property was purchased from Telecom. Noise and visual impact concerns were raised by the local community; ECNZ began a public consultation process with the intention of gaining resource consents for the project and completed its technical investigations, but progress was delayed by the decision to split up the corporation. Currently ECNZ is exploring other windpower projects both north and south of the Manawatu Gorge.

New projects for geothermal power generation are increasingly being explored as others consider becoming involved in generating. In 1994, after ECNZ had investigated the Mokai geothermal field for some time, the Tuaropaki Trust Board gained resource consents for a station. After several years' work in conjunction with ECNZ, it was announced in 1998 that a 50 MW geothermal station owned by the Trust would be built on the field. ECNZ has an investment in the project and a contract to operate the plant. It will also provide a hedge contract for part of the plant's output in order to ensure a secure cash flow for the project.

Rationalisation and improvement

While undertaking its strategic reorientation from the early 1990s, ECNZ continued to rationalise and improve the efficiency of its generating assets. In the early 1990s the emphasis in new power station development shifted from hydro to thermal stations with the increased availability of gas. A conceptual design and resource consents for the Taranaki combined-cycle station were provided and subsequently sold, investigations were made into repowering New Plymouth and Huntly, and land for a possible new thermal station was retained at the Marsden, Meremere and Otahuhu sites. A wide range of fuels was investigated for Marsden B — coal, oil, gas and orimulsion — but none proved attractive and it was decided to explore a sale instead.

By 1994 the emphasis in investigations for new generating capacity had moved to smaller projects



Marsden A and B chimneys come down by means of explosives.
New Zealand Herald, 21 October 1997.

— usually involving cogeneration and in association with a partner — because the continuing decline in wholesale electricity prices made it difficult to proceed with projects unless there were benefits in addition to electricity generation or unless costs could be reduced by, for example, embedded generation. ECNZ commissioned a 52 MW cogeneration facility at the Te Awamutu dairy factory in August 1995 using a gas turbine from Whirinaki. It also developed a 40 MW biomass cogeneration plant at the Kinleith pulp and paper mill in early 1998.

After the Meremere station was mothballed in early 1991, 1,800 tonnes of asbestos insulation was removed from it and staff were laid off. In November 1993 tenders were called for the sale of the station. ECNZ hoped to sell it offshore so that the station would not be used by a local competitor and it would retain the strategic land adjacent to the Waikato River.

After ECNZ failed to sell it to Asian buyers, Meremere has been offered to Nga Pua Waitanga (which includes Olivine NZ and other New Zealand investors). The company, which sees its investment as a world-leading initiative in recycling and energy generation, has an option for two years while resource consents are obtained. It plans to continue with the coal-fired station in upgraded form and build a new station that burns rubbish and sewage sludge in a high temperature furnace. As part of a Treaty of Waitangi settlement, the land on which the station is sited was returned to Tainui and is currently leased to ECNZ. Resource consents for the upgraded and new stations are still to be heard.

Marsden A was officially decommissioned in March 1997, when the last fuel oil was removed from its tanks and the tanks were sold and relocated to Fiji and other parts of New Zealand. In October the tall station chimneys were flattened by explosives. Marsden B is to be sold outside New Zealand, while Marsden A is to be dismantled apart from one unit which will continue in use for voltage control.

In the early 1990s ECNZ provided a conceptual design for a large combined-cycle station in Taranaki, to be fueled by Maui gas. There was some discussion of whether such a station should be sited close to the source of gas in Taranaki or close to the Auckland demand at the Meremere site. Resource consents for the project, the first new power station under the Resource Management Act, were applied for in 1993. However, when Simon Upton was appointed as Minister for the Environment, he called in the application under the Resource Management Act for special consideration as a result of concerns over CO_2 emissions. Plans for the station were thus put on hold for more than a year while a special inquiry was held into the station's environmental implications. The inquiry found in February 1995 that ECNZ could have air discharge consents if it planted sufficient trees (estimated at 4,000 hectares of plantings annually, at a cost of $2.5 million) to absorb the CO_2 that would be produced.

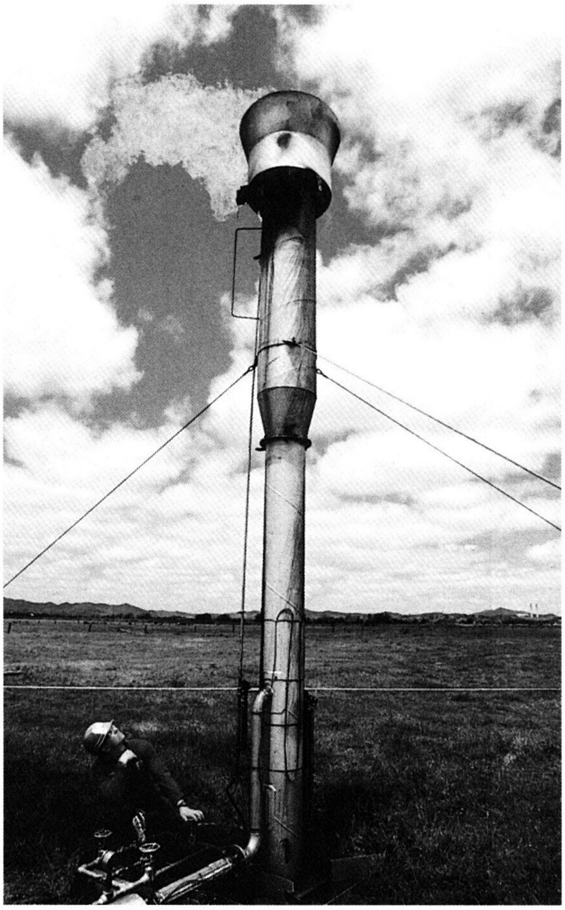
The direction in which the industry reform process was moving suggested that it was not possible for ECNZ to build the Taranaki station. The reform study of 1994 had recommended that the package of land, station design, gas and resource consents be sold. ECNZ thus put it on the market in 1995. The British National Power generating company showed an interest in purchasing the package, but it was eventually sold to a consortium of Fletcher Challenge Energy, Mercury Energy and TransAlta New Zealand in September 1995. The partners undertook to purchase much of the plant's output for twelve years at a price that would increase in real terms. Construction of the station began in October 1996 and was completed in mid-1998 at a cost of $340 million. It has a capacity of 379 MW.

A flurry of new generating projects in recent years showed that other companies were confident that they could provide power at a competitive cost. This, together with Contact Energy's commitment to take Maui gas and its need to sell New Plymouth power at a low price, posed a serious threat to the viability of Huntly, which increasingly came under scrutiny as its key role in the generation system was assessed and its production of CO_2 was highlighted.

In early 1997 ECNZ, having undertaken trials in late 1994, began seriously investigating the possibility of using gas produced by the conversion of coal in previously inaccessible seams underground. The goal was to assess a possible re-powering of one turbine on a combined-cycle basis that could both increase the station's output by 10–20 per cent and provide an alternative long-term source of gas. Both possibilities proved uneconomic in the environment of declining prices for electricity.

ECNZ made strenuous efforts to cut running costs at Huntly and make it more competitive with cheaper stations, including reducing staff numbers. In 1986 450 had been employed; in July 1997 the station lost 95 of its remaining 270 staff. It no longer made sense for ECNZ to run the station hard. Huntly closed over Christmas 1997 for the first time ever and it was little-used in 1998. ECNZ also took a stake in the Kupe gas field, in the process forging a relationship with Fletcher Challenge. ECNZ signed a Heads of Agreement with Fletcher Challenge on possible future gas supplies.

The upgrading of power stations continued. In June 1996 a fifteen-year upgrading programme that increased the Tokaanu station's capacity from 200 to 240 MW was completed. This involved



Gas is flared off from a well in the Huntly North coal field in November 1994, produced by an underground coal gasification process. This is based on the controlled burning of coal underground and piping of gas to the surface.
Waikato Times, 30 November 1994.

installing new stator windings, highly efficient turbine runners and a world first that won a design award — radial draught tube control gates.

In July 1996 ECNZ announced that it was to bore a second ten-kilometre-long tailrace tunnel for the Manapouri station at a cost of $200 million to increase its capacity to 760 MW. The need to improve the tailrace had long been apparent; unexpected frictional losses in the tunnel had restricted the capacity of the station to 585 MW rather than the planned 700 MW. Shutting down the station to enlarge the first tunnel would take too long and cost too much, but if a second tunnel was bored parallel to the first the station could continue to operate, except during a three-week period required to connect the tunnel to the station. Advances in technology meant that a huge machine could rapidly bore the tunnel.

Work began in early 1997 in preparation for the arrival of the tunnel boring machine, which was designed in the USA and built in England. The machine arrived in April 1998 and began work in June. It will work around the clock apart from shut-downs for maintenance, and hole-through is expected to occur in January and completion of the contract in October 2000.

At the beginning of 1997 ECNZ announced that it planned to install a new automation and remote-control system, based on 180 kilometres of fibre optic cabling, for the Waitaki hydro system. (Manapouri was to be automated also.) This scheme, which would cost $50 million and lead to significant staff reductions, was expected to produce an additional 125 GWh per annum through increased efficiencies. It would also assist in compliance with resource consents by allowing closer control of operations. The automation of power stations facilitates the co-ordination required by the competitive market by establishing a hierarchy of control through which the constantly changing demands of the market are translated into the optimal operation of individual power stations.

The five upper Waitaki stations with automated systems which were nearing the end of their lives would have these upgraded. Waitaki, Aviemore and Benmore would also be automated, and all eight stations controlled from Twizel. Waitaki was automated in June 1998; for the first time since its commissioning in 1934 there was now no one on site to operate the station. Waitaki is to be followed shortly by Benmore and Aviemore. In 1997 an upgrade for Aviemore, involving the installation of four new more efficient turbine runners by April 2000, was approved. The remote-control system for the Benmore spillway gates was tested in July 1998 with a spectacular peak flow of 3,400 cumecs that surpassed anything experienced since the dam's construction. Ohau B and C have also been upgraded, and with good progress being made on Ohau A and Tekapo A and B the project is expected to be completed in March 1999.

On occasion power stations have needed substantial repairs or modifications. In 1990 ECNZ commissioned a study of the likely downstream impact of a catastrophic failure of the Karapiro dam, and in 1993 Karapiro's old diversion tunnel was made operational and upgraded so that the lake could be lowered for safety purposes if necessary. In 1996 ECNZ called upon international experts to evaluate Karapiro's ability to withstand a major earthquake as part of a dam safety programme using SEED ('safety evaluation of existing dams') under which all dams are independently surveyed every six years. Reviews of ECNZ's studies concluded that the dam was safe but that some work was required to prevent possible slight movement of the left abutment in a massive earthquake. This work is currently being undertaken.

Following spectacular eruptions of Ruapehu and substantial deposits of ash from September 1995 on the flanks of the mountain and in the catchments for the Tongariro scheme, the Rangipo station had to be closed down in April 1996. Ash that had been washed into waterways was passing through the turbines and creating catastrophic erosion of the runners and huge holes in the wicket gate seals. The ash also cut into the control valves and inlet control gates. Some fifteen

Opposite above: Rangipo's turbine runners suffered disastrous damage (here outlined in white) from the ash washed into rivers after the eruptions of Ruapehu during 1995.

Opposite below: This most powerful 'open hard-rock' tunnel boring machine yet built is capable of boring a 10-metre-diameter hole 21 metres a day through the solid granite of Fiordland. It weighs 1,000 tonnes and has a rotating cutterhead with 68 cutters, requiring regular replacing. Behind it is a long 'backup system' that sprays the tunnel walls with concrete, conveys the spoil and muck away from the face and contains tearooms and toilets.

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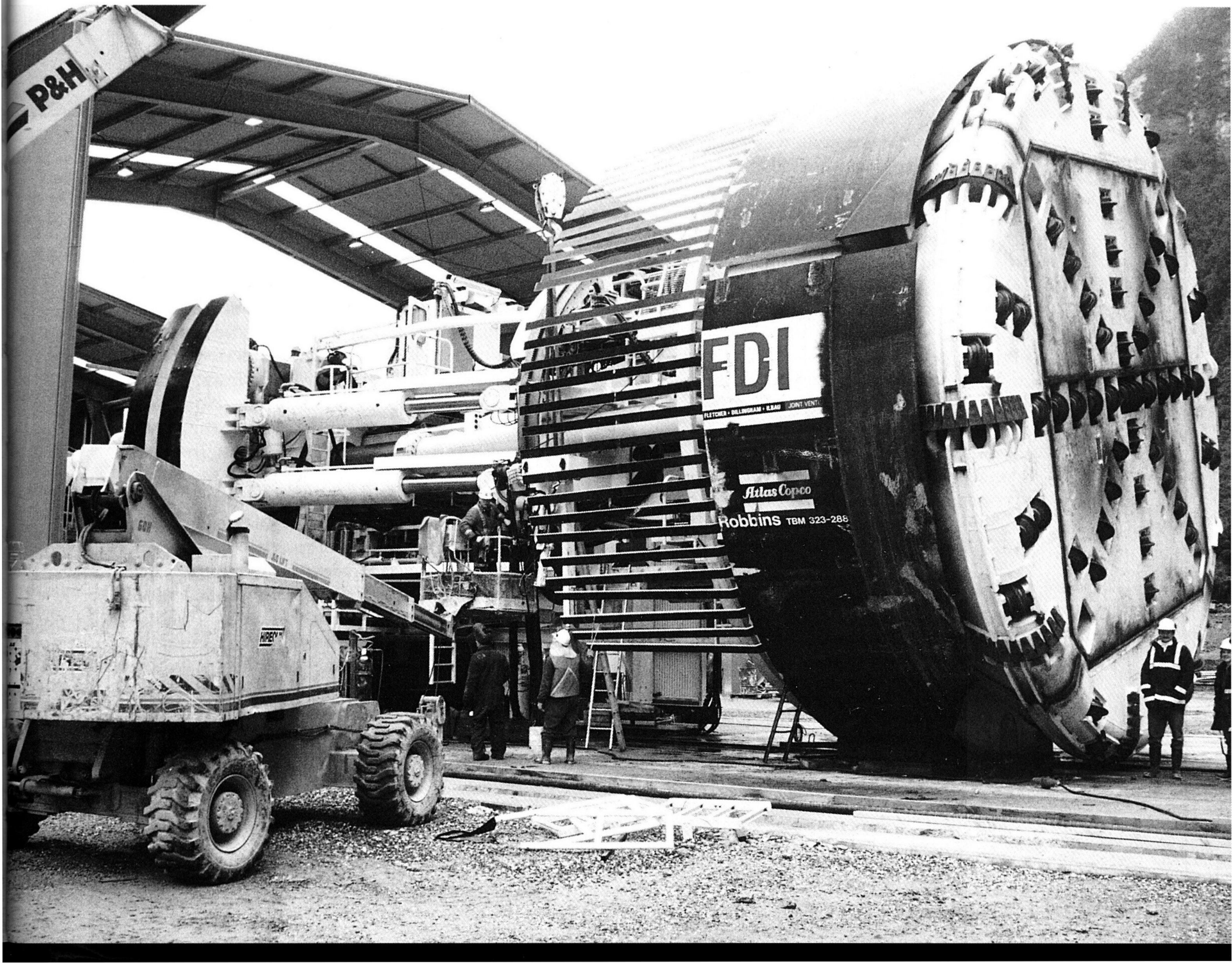
P&H
FDI
FLETCHER • DILLINGHAM • ILBAU JOINT VENTURE
Atlas Copco
Robbins TBM 323-288
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years' wear to the runners occurred in the space of seven months. The station was closed for nearly a year while special blades were machined in New Zealand and then hardened and coated with ceramic material overseas before being installed. ECNZ investigated ways to minimise the intake of ash and shut the station down when ash was in the water. The new turbine runners have proved durable. While the ceramic coating wore away, the hardened steel resisted the abrasion successfully. It also appears that the ash has washed away faster than thought because of floods in the catchments.

When it was found after some years of investigation that earthquake faults under the Matahina dam were active and that the structure did not quite meet international earthquake standards, ECNZ decided in 1996 to strengthen it by constructing a leak-resistant rockfill downstream buttress at a cost of $60 million. To ensure safety, the lake was lowered in July 1996. Some 1.3 million cubic metres were excavated from the rockfill shoulder and replaced by 1.8 million cubic metres of material. The strengthened dam was slightly higher than before to prevent it being overtopped during an earthquake. A twenty-metre-deep cut-off trench was excavated along the length of the dam to drain and help stabilise it. After this strengthening was completed ahead of schedule, the lake was refilled and the station was put up for sale in August 1998.

Following the 1995 memorandum of understanding leading to the establishment of Contact Energy (see Chapter Sixteen), ECNZ began to sell its smaller regional hydro stations such as Matahina, Mangahao and Lake Coleridge. Under the terms of the memorandum ECNZ had to await government consultation with Maori interests, following which it had eighteen months to effect a sale. The small West Coast hydro station, Arnold, had already been sold to Westpower in 1994 for $7 million.

In 1992 upgrading work began on the old Mangahao station, commissioned in 1924. A number of improvements made in 1988 had already increased its annual generation by 15 GWh. The communication system for the reservoirs had been greatly improved and leakage from them eliminated, while the powerhouse switchgear and control systems had been replaced because they were hazardous and likely to fail.

Between 1992 and 1994 Mangahao was automated and three of the old Pelton wheels were replaced by a more efficient horizontal Francis turbine producing 26 MW. The station was shut down for two months while two of the four penstocks were replaced by a single, larger penstock. The remaining two Pelton wheels were upgraded to yield a total of 6 MW. The old control panels were left in place as a museum piece. The upgrade raised the station's capacity from 21 to 32 MW and allowed another 27.5 GWh to be generated annually. In 1997 Mangahao was sold to a partnership of King Country Energy and Todd Energy for $53.5 million.

In October 1998 the historic Lake Coleridge station, the first major government hydro station commissioned in 1914, was sold to a consortium of Alpine Energy and Trust Power for $90.6 million. With this station passing out of the state's hands an era had come to an end.

As well as selling some smaller regional stations, ECNZ sold both PowerMark and DesignPower (the company that had been formed from PowerDesignBuild when PowerMark was formed). PowerMark had been created from a merger between the electrical contracting arm of Electricorp Marketing (EMEC) and PowerBuild, a subsidiary of PowerDesignBuild, in April 1991 in order to create a single large electrical company and to eliminate competition between the corporation's two contracting arms. While much of its work was done for Trans Power, it also began to undertake communications work. PowerMark was sold to GEC Alsthom, a large international company, in April 1995.

DesignPower had struggled as the amount of work it was doing for ECNZ fell with the completion of major projects, and as it was made clear that it would have to survive on its own merits. While it did get work when the corporation was engaged in substantial projects, such as the refurbishment of Arapuni and automation of North Island hydro stations, this was not sufficient for it to remain viable. However, in 1991 it secured a role in developing the Wayang Windu geothermal power project in Indonesia, providing work to the present day.

In 1992 the Genco report emphasised that the company remained within ECNZ as an investment rather than as part of its core business. Since 1994 it has undertaken work on the large Upper Krishna hydro-electric project in India, and in an engineering consultancy for the Malitbog geothermal power project in the Philippines.

ECNZ eventually also decided to sell its engineering consultancy arm, DesignPower. It was acquired by the American international engineering consultants Parsons Brinckerhoff in

Work continues on the rockfill shoulder for the Matahina dam in order to strengthen it, October 1997.

early 1998. It had contributed greatly to the development of cogeneration and windpower in New Zealand, and engineered the cogeneration plants at Te Awamutu (52 MW), Bay Milk (10 MW), Glenbrook (74 MW), Kapuni (25 MW) and Kinleith (40 MW). It was involved in the establishment of New Zealand's first windfarm — Haunui, operated by Wairarapa Electricity — and under its new owners is involved in other wind-powered projects. DesignPower also provided a conceptual design for and supervised the detailed design of the Taranaki combined-cycle plant.

Conclusion

Over the last decade ECNZ has dramatically changed its organisational structure, size and objectives while it has sought consistently to increase efficiency, lower costs and improve public perceptions of its performance. (For summary statistics of its performance see Appendix 4.) A review of its performance in early years concluded that profit, return on assets, productivity and volume of sales had substantially increased.[22] Since that time real prices and operating costs have decreased and staff numbers have continued to shrink as a result of contracting out. By 1997 the corporation employed fewer than a thousand staff (less than one-third of the number in 1991), as a result of the impact in recent years of the increased use of computers, contracting out and centralisation, together with the separation of Trans Power in 1994, sale of PowerMark in 1995, and the splitting off of Contact Energy in 1996. The sale of DesignPower and further rationalisations in 1998 saw staff numbers fall to 581, about 10 per cent of the number employed prior to corporatisation.

These changes have not entailed staff reductions for their own sake; they have arisen as a result of the corporation's increased efficiency and changing situation. Between 1987 and 1997 ECNZ was able to improve its overall efficiency by 15 per cent, equivalent to 1,000 MW of capacity, by virtue of improved operating and maintenance processes.[23] ECNZ ranks highly in comparison with other large New Zealand and overseas companies — it is a well-run organisation with an efficient treasury function, appropriate internal disciplines, effective communication, and an innovative change-based culture in which structures are related to corporate strategies and objectives. The successive reorganisations have given rise to a much smaller, flatter and less hierarchical managerial structure with decentralised and delegated authority in which people are encouraged to display flexibility and a range of skills.

ECNZ has performed well as a commercial company. It has attained excellent credit ratings and has successfully refinanced debt. It has consistently yielded high profits to its shareholder the government, and it has paid very substantial taxes. Between 1987 and 1998 ECNZ returned $6 billion to the government (as shareholder) in the form of dividends and taxes. It has been able to maintain a high return on equity. The rate of return on shareholder's funds has been consistently high, and in 1998 its highest-ever rate of return of 14.8 per cent was posted.

The impact of this improved efficiency and excellent commercial performance has been felt in the wholesale price of electricity, which has fallen in real terms throughout most of the period and is now 23 per cent below the price in 1988. The real cost of producing electricity has also fallen greatly, and is low in comparison with similar companies in other countries. In overall terms ECNZ has reduced this cost by about 30 per cent since 1987, and it expects further significant reductions can be made in the future. These impressive achievements have been made in spite of the considerable instability and uncertainty generated by the reform process.

We now turn to the place of the corporation in the wider reforms. ECNZ has been unable to convince the public or the politicians that the substantial improvements in efficiency presented a case either for leaving the corporation as a single entity or for its privatisation. This has meant, ironically, that ECNZ's success has only reinforced a determination to break down its perceived monopoly.

CHAPTER SIXTEEN

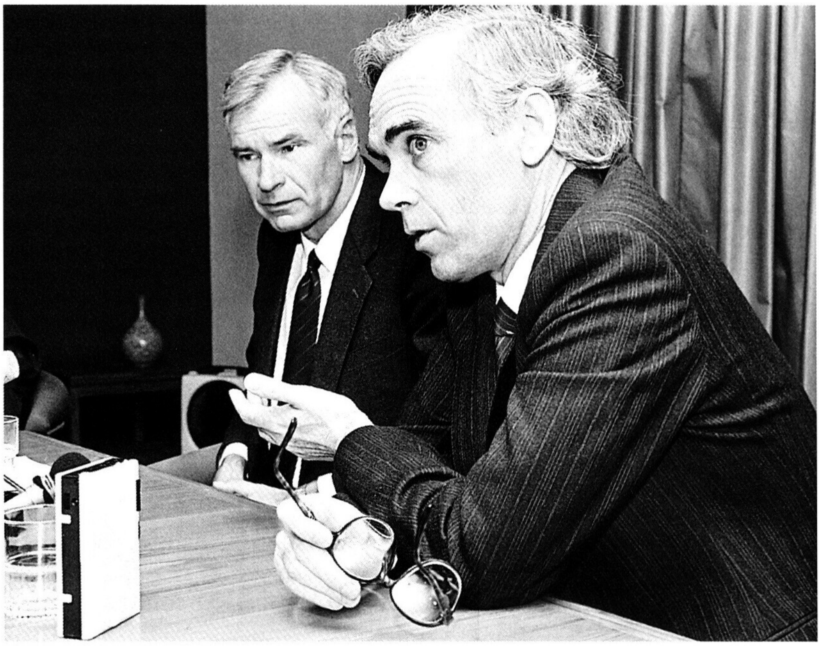
From Corporatisation to Break-up

ECNZ VENTURED FORTH CONFIDENTLY into a new future in which it assumed it would be master of its own fate but, in spite of increasing efficiency and success as an SOE, its wish to be privatised would not be fulfilled. The pressures for diminishing its perceived monopoly mounted as political realities made their presence felt, and the logic of the market model was redirected towards breaking up ECNZ while it remained in government ownership rather than at the point of its privatisation.

Valuation

While those in charge wanted to get on with the job of running the new corporation, negotiations over the valuation of ECNZ's assets were protracted indeed. They had begun in late 1986 with the intention of formalising the SOE arrangement prior to corporatisation. The negotiations between Treasury and ECNZ were critical and reflected crucial philosophical differences; their resolution would determine the strategic direction of the wholesale electricity industry. A low valuation would allow a high rate of return and the opportunity to keep prices low or lower them even further but would discourage competition, while a high valuation would increase incentives to perform better but would necessitate raising prices to maintain a reasonable rate of return and make it easier for other companies to enter generation.

In December 1986 ECNZ made an initial offer of $3.7 billion, based on a private-sector method of assessing value in terms of a ratio between earnings and the price paid for a business, and an assumption that there would be little movement in real prices. Treasury responded in mid-March 1987 with a figure of $8.5 billion, calculated on the basis of the net present value of the discounted cash flow projected over a long time period and with a substantial rise in real prices. (This approach is based on expected future earnings discounted to present-day terms.) The corporation believed that reasonable returns were essential, and that even on its own valuation of $4–5 billion returns would be below market averages. (Its book value was $4.3 billion.) Although in late March ECNZ raised its estimate



John Fernyhough, Chairman, introduces ECNZ's new Chief Executive, Dr Roderick Deane, right, to the public in April 1987. The two formed a formidable partnership that was to the corporation's great advantage.
New Zealand Herald, 14 April 1987.

and Treasury seemingly reduced its figure the gap was unbridgeable. Failure to obtain agreement meant that on 1 April 1987 the corporation had to commence its existence under a licence from the government for the use and management of the assets including the Clyde and Ohaaki construction projects.

Over the succeeding months ECNZ itself produced a range of valuations based on projections of long-run marginal costs (the cost of producing electricity from the next station to be built). All were substantially lower than Treasury's. At the same time it began to develop its own strategy independently of the valuation exercise and started to move towards 'entry limit' pricing to deter potential entrants to generation. At a time of surplus capacity, competitive price levels were more closely related to lower figures associated with the short-run marginal cost (the cost of additional supply using existing resources) than to the long-run marginal cost. The corporation believed that this would be in accordance with the expectations of consumers that amounted to an implicit contract. With ECNZ raising the assessment of its value somewhat, to its consternation Treasury began talking of $10–11 billion.

In September 1987, after fruitless discussions and following Labour's re-election, ECNZ sought the assistance of Ministers to help break the impasse. In November the government told the two parties to come to an agreement that month, under threat of a decision being made for them by the Minister for State Owned Enterprises, Richard Prebble, and the Minister of Finance, Roger Douglas. The issue remained unresolved even after an extension of the deadline, and responsibility for the decision was put in Cabinet's hands. It appeared that Prebble and Douglas could not agree on a valuation either, and by March 1988 mediation by Sir Ronald Trotter, a key adviser to the government, was being suggested. It appears that ECNZ's bid was $5.5 billion, with a small margin if final agreement could be clinched, but Treasury would not go below $8.5 billion.

Meanwhile the corporation was beginning to firm up its approach to pricing. It was agreed that the valuation should not necessarily dictate pricing policy, and that the corporation should seek a commercial return without increasing prices in real terms immediately if possible.

The valuation issue was finally resolved in Treasury's absence at the end of March 1988 at a figure of $6 billion plus $300 million for net working capital. Following a Wellington Arts Festival event, Trotter arranged a secret late-night meeting on Thursday 24 March. He asked Prebble and Douglas to come in while Treasury officials were 'safely tucked up in bed'. He and Deane rehearsed the pertinent figures outside, crouching over car headlights to read the piece of paper. The meeting, in Deane's words, 'started late, and finished later' — in the early hours — and the deal was finalised next morning. Trotter conducted it like an auction, presumably drawing upon his considerable experience in Wright Stephensons. The final total figure of $6.3 billion comprised $3 billion of debt, $2.5 billion equity in ordinary shares held by the Crown and $800 million in government 6 per cent redeemable preference shares (these were to be treated — to ECNZ's advantage — as equity rather than debt). The $3 billion debt to the Crown entailed an initially high interest rate that was to fall with successive repayments.

Matters still to be sorted out included the transfer of the contracts for the completion of Clyde and Ohaaki and land assets to the corporation. The Clyde and Ohaaki contract obligations followed in April, with the Clyde project proving to be less straightforward subsequently because of a large claim on the government for compensation for additional gorge stabilisation work.

As a result of the valuation, together with costs relating to restructuring and other financial outlays, the corporation made a small net profit after tax of $141 million, a rate of return on assets of only 4 per cent in its first financial year. But as it turned out valuation proved less central than pricing; the corporation was able to provide good profits and excellent rates of return in subsequent years.

With agreement on ECNZ's valuation having been reached, state assets worth more than $10 billion were formally handed over in a ceremony in the Beehive on 31 March 1988 to the six SOEs: ECNZ, Telecom, Government Property Services, New Zealand Post, Airways Corporation and Coal Corporation.

Following the agreed valuation and the signing of a sale and purchase agreement, ECNZ embarked on what was described as one of New Zealand's largest ever corporate borrowing programmes — it had to find about $1 billion annually for three years to repay its debt to the government. (The corporation had decided that it should repay the debt even faster than the five-year period proposed by Treasury, in order to become independent as soon as possible.) Its

Bank of New Zealand
Cheque Duty Paid
Date 11 01 1988
Electricity Corporation of New Zealand Limited
Pay Her Majesty's Government
or Bearer
The Sum of Six Billion Three Hundred Million Dollars Only
$6,300,000,000.00
for the Electricity Corporation of New Zealand Limited

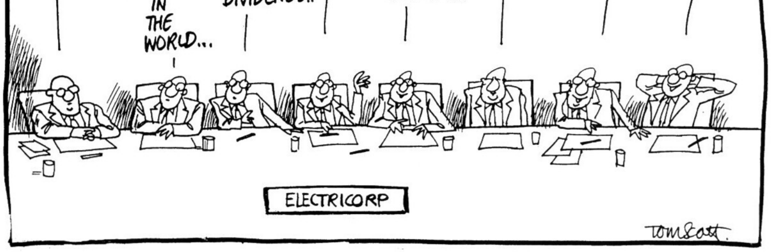
'Whopper cheque'. John Fernyhough, Chairman of ECNZ, (right) hands over a cheque for $6.3 billion to Roger Douglas, Minister of Finance, (left) and Richard Prebble, Minister for SOEs, (centre) in the largest commercial transaction in New Zealand's history.
Evening Post, 15 April 1988.

cause was aided by very high credit ratings from both Standard and Poor's and Moody's, and it successfully refinanced its debt within the agreed period.

Privatisation?

With the matter of asset valuation resolved, attention turned towards the longer-term future of ECNZ. Was the corporation to be privatised, and were its generating assets to be broken up into smaller competing entities as the retail power companies wished? While it seemed a logical and obvious step to economic rationalists, the process whereby competition was introduced into the generating side of the industry proved to be both complex and protracted. Political considerations had to be taken into account, and a myriad of consultants, government agencies and other interested parties vied for position over a number of years. ECNZ pushed for privatisation so that its commercial objectives were clearly separated from political considerations, but politics in the end prevailed.

Both Deane and Fernyhough favoured continuing the process of reform by privatisation rather than breaking up ECNZ, although they were prepared to accept the separation of Trans Power as a trade-off for privatisation.[1] They wanted to prepare the corporation for privatisation by making sure that it performed really well and was attractive to potential purchasers, and felt increasingly that the SOE model was a difficult halfway house in which politicians had the scope to


OF COURSE, IF WE WERE PRIVATISED WE COULD RAISE POWER PRICES AT WILL...
WHO'S GOING TO PRIVATISE US WHEN WE PRODUCE THE MOST COST EFFICIENT ELECTRICITY IN THE WORLD...
ESPECIALLY WHEN WE'RE MAKING RECORD PROFITS AND PAYING THE GOVT HUGE DIVIDENDS..
HEY! WE COULD THREATEN TO PUT POWER PRICES UP...
YEAH! WE COULD ARGUE WE NEED TO PAY FOR FUTURE GENERATING CAPACITY...
THE WHOLE COUNTRY WILL SCREAM ABOUT GREEDY MONOPOLIES...
HARDLY ANYONE WOULD OPPOSE US BEING SOLD OFF...
THEN WE COULD RAISE POWER PRICES AT WILL...
ELECTRICORP
TOM SCOTT

A cynical view of some of the issues surrounding privatisation. The proposed price increase of 1991 proved to be a crucial ingredient in the failure to privatise.
Tom Scott, *Evening Post*, 17 July 1991.

interfere with business decisions. Treasury also supported privatisation. Prebble actively pursued a privatisation agenda in the context of Douglas's 1987 and 1988 Budgets, which envisaged asset sales to reduce public debt. Prebble asked all SOEs to examine their possible sale, and in March 1988 the government set up a State-owned Enterprises Steering Committee, headed by Trotter, to deal with SOE relationships with the Crown and facilitate moves towards privatisation.

But, as the Labour government increasingly lost its way and the reform process became blunted during 1990, opposition to privatisation mounted and the focus shifted to breaking up ECNZ. Those who saw the corporation as a monopolistic monolith and others who believed competition would be best served by a greater number of smaller competing generating companies could combine in this cause. From the perspective of the power companies and various consumer groups, the issue was one of market power and a sole electricity generator (whether state-owned or private-sector) that could hold the country to ransom.

In May 1988 a task force was formed to examine the structure, ownership and regulation of the electricity industry, with a brief to consider how best to enhance its economic efficiency. In the background was concern over the dominant position of ECNZ and a Treasury proposal to break it up into three competing companies. Initially the task force was to look only at the wholesale part of the industry prior to its privatisation, and to consider specifically the need to separate the transmission system. ECNZ indicated that it was already carrying out many such reforms internally, and urged successfully that the study include electricity distribution also.

While Treasury pressed for a radical break-up, ECNZ argued for more cautious reform in conjunction with minimal regulation. The work of the task force proceeded relatively uneventfully from ECNZ's point of view — it appeared that the weight of evidence was against a wholesale break-up.

The task force reported publicly in September 1989.[2] ECNZ was largely happy with its conclusions, observing that virtually all the consultants engaged for the task force's work considered that an integrated system was more efficient, and remarking that competition was a means to an end, not an end in itself.[3]

The report recommended that competition in generation should be encouraged by minimising entry barriers and developing a wholesale market for electricity; that there should be no large-scale break-up of ECNZ, but further investigation should take place on how to minimise barriers to new generating companies through 'light-handed' regulation or the 'spin off' of some non-core stations; and that ECNZ should be privatised subject to the satisfactory development of competition in generation.

The problem in relation to breaking up ECNZ was that different forms of efficiency worked in different directions. A break-up would be likely to diminish both the 'productive' efficiency of joint dispatch and the 'dynamic' efficiency of centralised planning. The trick would be to create such a combination of conditions that overall efficiency would be enhanced compared to the existing situation. No one, apart from some Cabinet Ministers, was particularly confident that such a change could be accomplished.

The task force was much less equivocal on other parts of the industry. It recommended that Trans Power should be separated from ECNZ and that retailers of electricity should become companies and have their franchises removed. Most of its recommendations came to pass in the following years — this document set the scene for nearly a decade of comprehensive reform of the electricity industry.

The government largely approved of the task force's recommendations, but agreed with the urgings of officials that further work should be done on contestability in generation, including the potential breaking up of ECNZ, which should remain an SOE in the meantime.[4] A subsequent officials' report widened the range of options, despite ECNZ's perception that the matter had been settled and that the narrow economic analysis demanding a break-up ignored the practical, technical and commercial issues. A majority of officials felt that spinning off selected stations would be beneficial but were uncertain about a larger-scale break-up. A study by the New Zealand Institute for Economic Research found that the gains in competitive efficiency from a break-up would not outweigh the losses in dynamic efficiency.[5]

Prebble, increasingly isolated in Cabinet, continued to press for privatisation by means of a partial break-up. In August 1990, he asked ECNZ specifically to examine the break-up question. Officials, while conceding that no clear option had emerged, argued that consideration of ownership and regulation issues pointed towards a spin-off of some stations followed by privatisation if competition was successfully introduced.

The corporation decided at this point that it would accept a limited form of break-up as part of a package with privatisation. Retention of the core of the generating system to minimise risk was identified as ECNZ's key objective. The corporation's subsequent report sketched out four possible groupings, with a core generating group based on the Waikato/Tongariro and Waitaki systems, supplemented by some thermal stations. In its view small companies lacked economies of scale, were likely to duplicate management and technical resources, and might require additional funding. The benefits of existing co-ordination, especially across river systems, would be lost, and there were possible adverse effects on the stability of the power system and dynamic efficiency losses arising from unco-ordinated investment decisions. ECNZ emphasised that a core generator should remain to underwrite the system, and that the break-up needed to be carried out sequentially to limit the risks involved.

The corporation wanted to make it crystal clear that an extensive break-up would not only see costs exceeding benefits but also reduce substantially the value of the government's investment. The Labour government was nevertheless keen to press ahead. Prebble asked for further detailed and practical work to be done on a break-up as a prelude to privatisation, involving the feasibility of creating a 'power pool' based on the British model but without its heavy regulation.

National, in Opposition, was much more cautious and sensed electoral advantage in holding back. When Deane gave a speech (misquoted in newspapers) in early 1989, advocating privatisation and warning of the dangers of political interference, he was rebuked by National leader Jim Bolger. A telephone conversation between the two calmed the waters, but National remained unenthusiastic about the reforms. Its policy, released at the Electricity Supply Association's conference in September 1990, was ominous in emphasising protection of consumers, regulation of prices and constraints on ECNZ.

National indeed replaced Labour before ECNZ's further work on a break-up was done. At first it appeared that privatisation had returned to the agenda. The new Minister of Energy, John Luxton, indicated that if individual stations could be sold for more than they were worth to ECNZ this would be considered.[6] Doug Kidd, the new Minister for State Owned Enterprises, encouraged ECNZ to begin work on a suitable mechanism for privatising the corporation and noted that a public share float was possible. Deane and Fernyhough offered to resign at the point at which privatisation took place in order that there would be no perceived conflict of interest.

ECNZ meanwhile reported to Kidd that a break-up would not give rise to efficiency gains.[7] Studies suggested that even a radical break-up would not eliminate collusion in fixing prices in a pure, unregulated spot market. The potential loss of efficiency from reduced co-ordination could be minimised by retaining core hydro stations, while a smaller-scale break-up could result in similar levels of competition without collusion if a contracts-based market was introduced.

The studies suggested that negotiations proceed on the basis of a combined spot and long-term contract market, with deferral of break-up or privatisation until after the market was established. This was in effect what ensued, after a considerable interregnum during which ECNZ's political position was dramatically redefined and privatisation was no longer an option. Fernyhough and the corporation placed most importance on contestability within a market context. If heavy-handed regulation was imposed, considerable costs would be incurred.

The politics of pricing

In 1991 the question of electricity pricing came to command public attention. While asset valuation was political enough, the issue of pricing went to the very heart of New Zealanders' long-standing expectation that electricity was a cheap service provided by the state. Compounding this was the strong public reaction against corporatisation. In combination this provided a force that politicians found hard to resist. ECNZ failed to anticipate the strength of these pressures when it sought what seemed to it to be a modest price rise.

From 1987 ECNZ had devised a pricing strategy based on combating the threat of new generation competitors entering the market. As Treasury continued to anticipate a long-term increase in real prices, ECNZ moved in the opposite direction, towards holding or even dropping prices in real terms. Following the opening up of generation to others a number of potential competitors appeared on the horizon, in particular the Auckland Electric Power Board with plans for a gas-fired combined-cycle station and the plan by CRA (Conzinc Riotinto of Australia) for a coal-fired station in Bream Bay, Northland. These threats suggested that ECNZ should bring down its prices closer to the short-run marginal cost — which in a situation of surplus generating capacity was little more than half the long-run marginal cost and below current wholesale prices. When surplus capacity was used up the price could be gradually brought back up towards the long-run marginal cost.

The issue was how much lowering prices would affect the rate of return. By July 1988 the strategy had been determined. Price increases were to be held below the rate of inflation so that the price gradually declined in real terms. While this would mean a lower rate of return in the short to medium term, this was perceived as a necessary cost of competition.[8]

Such a policy confounded the expectations of Treasury and many in the industry, but it comfortably fitted with New Zealanders' expectations. Over the next year the strategy was refined and in June 1989 it was formally announced that there were to be real price reductions over the next three years.

In 1991, however, by which time the price had declined by 20 per cent in real terms, ECNZ began to revise its thinking. Its strategy had been successful in deterring competitors, and the corporation had successfully negotiated contracts for Maui and other gas sources that gave it control over supply. Later in the decade there would be a need for new capacity, for which construction would need to commence within a few years. ECNZ now argued that prices should gradually rise to the long-run marginal cost to encourage new entrants.[9]

The nub of the problem became not an economic but a risky political one: would the public, power companies and politicians wear a price rise? With the election of National a marked increase in ministerial involvement in ECNZ's affairs had been noted. The corporation decided in the end to notify its customers in the usual manner that the electricity wholesale price would increase by an average of 3 per cent for the year. To the shock of the company this provoked a storm of protest.[10] It became apparent that a serious miscalculation had been made.

ECNZ argued that its monopoly position was largely theoretical, but its protestations had little effect.[11] It failed to reach agreement on prices with many retailers, and the Electricity Supply Association of New Zealand urged its members not to agree to any increase in price. The corporation faced a predicament about which it could do little since it was not in a position to enforce the new prices and its relationship with the power companies reached a low point.

An indication of this effective lack of monopoly power lies in the long-standing dispute that ECNZ had with one of its major customers, the Auckland Electric Power Board (later Mercury Energy), arising from changes in its contractual arrangements. In the late 1980s ECNZ and the Board could not agree on the replacement for the bulk-supply tariff and a long drawn-out legal dispute ensued, part of which (concerning the interpretation of SOE powers, rights and duties) went to the Privy Council. Eventually the matter was settled in 1995 partly as a result of changes of personnel in both organisations. ECNZ had to forgo some of the revenue it might have expected, while Mercury Energy had to accept that the bulk-supply tariff era was at an end.

A rift appeared between ECNZ and the government, which was concerned not to damage the economic recovery. A July 1991 *New Zealand Herald* headline quoted the Prime Minister, Jim Bolger, as accusing ECNZ of lying about the increase.[12] Bolger was subsequently forced to withdraw unreservedly the allegation. Kidd meanwhile threatened that the government might have to sack the ECNZ Board if it did not back off.

The government asked the Commerce and Marketing select committee to inquire into the proposed increase.[13] It found that there was no justification for the increase (or for the associated reduced South Island differential) and did not accept the long-run marginal cost argument. It suggested that prices would have to increase by at least 20 per cent over ten years if this argument was accepted. ECNZ already received a good rate of return and more emphasis should be placed on energy efficiency. The committee recommended that the government effectively call the corporation to heel, failing which it should revise the corporation's statement of intent or impose regulations.

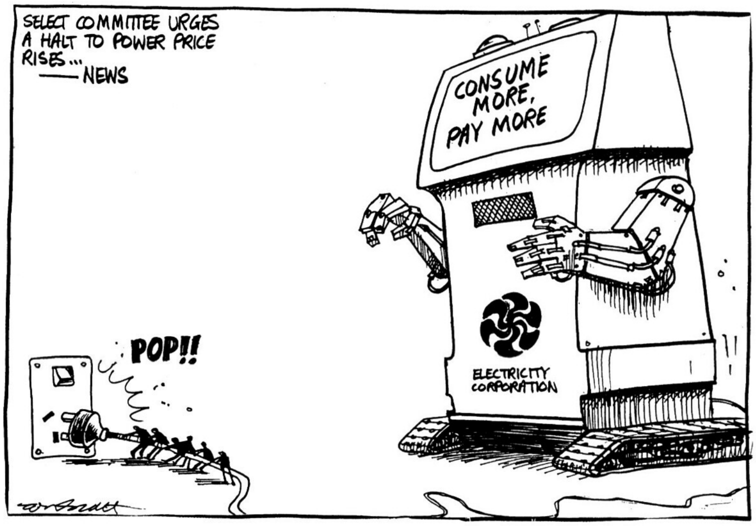
ECNZ's strategic position began to shift as the select committee deliberated and as the corporation realised that it had crossed an invisible boundary defining what was possible. The corporation began to emphasise the establishment of a wholesale market that would take price-setting out of the political arena. In ECNZ's view, this would have similar results in the longer term by relating prices to the cost of producing electricity.

When the select committee's report was released Bolger noted that it confirmed his opposition to an increase in the price of electricity. The government and ECNZ warily circled around an issue that had now become deeply political. Bolger declared that while the government would not be acting formally on the recommendations of the select committee, he did not think there was any likelihood of a substantial increase. ECNZ announced that it was to increase prices only by 1.5 per cent, after a pause for six months. It accepted that electricity prices were now to be determined politically.

During this episode, ECNZ felt for a time that the forces supporting privatisation had actually been strengthened. The corporation saw political interference in pricing decisions as bolstering rather than weakening its case. Ruth Richardson, the Minister of Finance, appeared to favour the privatisation of ECNZ, and Treasury pushed for it to be considered after the July 1991 Budget. The corporation now looked at the possibility of a linked spin-off and privatisation. Kidd, McTigue and Luxton all publicly favoured a split, which could be initiated by restructuring the company so that two small companies could be spun off from it to facilitate privatisation before the 1993 election.

Nonetheless, the National government from the middle of 1991 effectively set itself against privatisation. In October Bolger indicated that privatisation was off the agenda, at least until after the next election. It became clear that pursuing this line would bring the corporation into a collision course with the ranks of the National Party. Work was redirected into developing the wholesale market, the pricing strategy, and retail reforms. The seal was put on the issue, at least for the foreseeable future, by the isolation of Richardson in Cabinet and Bolger's subsequent emphatic statement prior to the 1993 election that ECNZ was not for sale.

The Genco report of March 1992 expressed ECNZ's own internal reorientation. Fernyhough's conciliatory public announcement of September 1992 — which included an offer to work with the government to promote more competition, including the splitting of ECNZ if this was desired — took this into the public arena. The Taranaki combined-cycle project was offered as a concession. The corporation thus faced new challenges, foremost amongst which was the resurrection of industry reform. ECNZ's new approach would be put to the test as the separation of Trans Power and the creation of a competitive wholesale market became more of a reality, and as industry studies were supplanted by political decisions on the new generating regime.

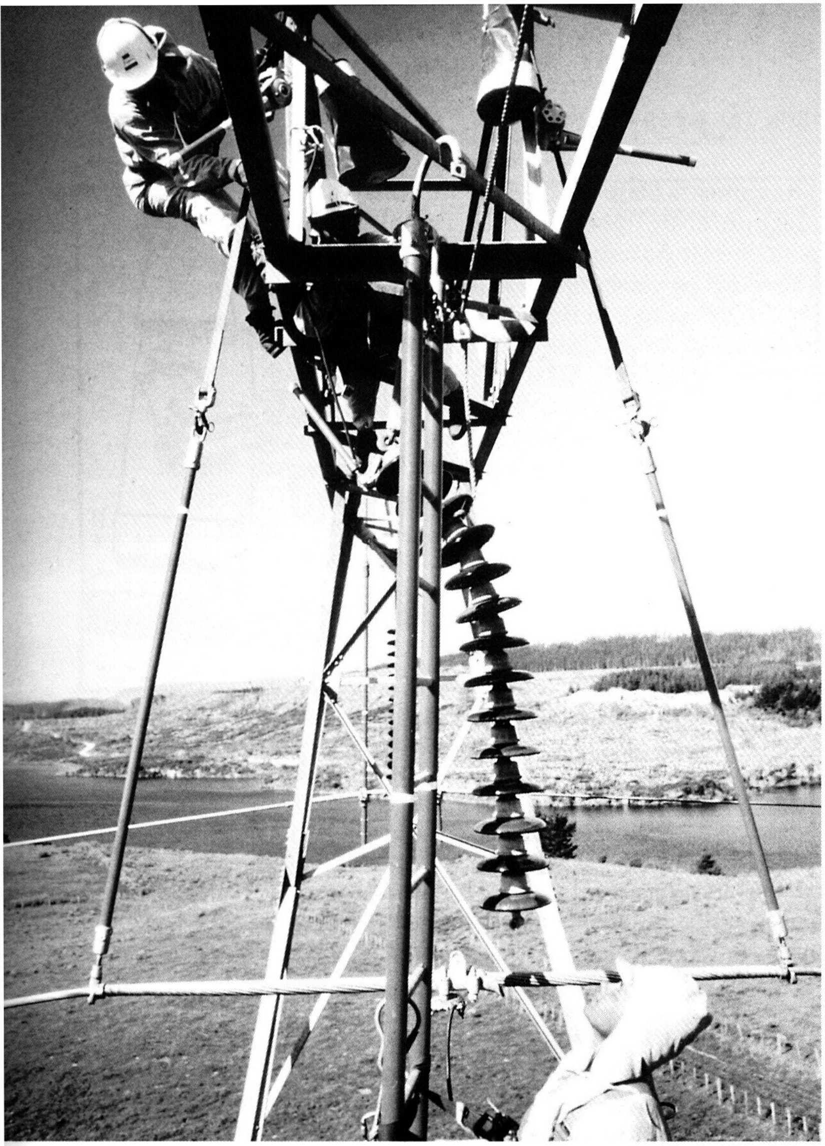

SELECT COMMITTEE URGES A HALT TO POWER PRICE RISES... —NEWS
CONSUME MORE, PAY MORE
POP!!
ELECTRICITY CORPORATION

The public's view of the role of the parliamentary select committee enquiring into the price rise proposed in 1991.
Tom Scott, *Evening Post*, 7 February 1992.

Towards a wholesale market

A major element of the reforms was the separation of Trans Power from ECNZ. The ground for this had been prepared over a number of years. ECNZ had effectively separated Trans Power within its own structure by establishing it as a subsidiary autonomous company in March 1988, and in transferring spur lines and substations (2,200 kilometres of line and 185 substations worth $500 million) to it from Marketing in early 1990, in line with the philosophy of 'ring-fencing' transmission lines. However, it was reluctant to accept the necessity for a formal separation, arguing that its monopolistic position was overstated and that co-ordination would suffer as a result.[14]

But separation was a trade-off for leaving the corporation as a single generating entity. The 1989 task force had recommended separation, that the resulting company should be subject only to light-handed regulation and, after much debate, that it should be owned by a 'club' of generators and distributors, thereby in effect partially selling off the grid to the industry, albeit in the form of non-tradeable shares. Separation, in what was to prove a very optimistic target, was to take place by 1 July 1991.



Maintenance work takes place on the national grid. Trans Power commenced a five-year upgrade in the early 1990s.

The government accepted these recommendations but asked for further work to be done on the club concept. There was general agreement on the principle that, as a natural monopoly, the national grid should retain its integrity but be separated from the remainder of the electricity industry. All in the industry should have 'free and equal' access to transmission and any suggestion of cross-subsidisation would be eliminated. Trans Power should be responsible for maintaining security and supply standards, and should facilitate access and compliance by transparency and monitoring. But the ownership form that a separated transmission system should adopt and the shape that the charging system should take were hotly contested and immersed in political considerations.

ECNZ, which was opposed to a transitional SOE form, accepted the club proposal, but the power companies were adamantly opposed to ECNZ or other generators having a share in Trans Power. They argued that the grid should be wholly owned by themselves on behalf of consumers but without having to pay for it. This became a crucial stumbling block to progress in separating Trans Power and focused the antagonisms that the power companies felt towards the corporation.

The uncertainty undoubtedly did not assist with the continued operation of the grid, which was beginning to suffer from ageing equipment and a lack of maintenance. Trans Power commenced a substantial five-year upgrade which would cost $72 million. In 1991 two very serious power failures underlined the need to improve reliability. Chief Executive Bob Thomson promised a tightening of standards but, when further cuts occurred later in the year, he admitted that the company was 'shell-shocked' by the earlier major failures and was spending $52 million on upgrading substations as a result.[15] Reliability subsequently improved.

In 1991 the National government accepted the need for separation of the grid but instructed the Trans Power Establishment Board to examine a range of ownership options. The Board nonetheless persisted in recommending club ownership.[16]

The valuation of assets was crucial to the separation process. ECNZ valued the grid at $2.828 billion, close to its book value. Shortly thereafter the Establishment Board released its slightly lower valuation of $2.572 billion, based on an optimised deprival value methodology (calculated on the basis of a commercially sustainable process of renewing assets). This methodology, which had originated from ECNZ for the immediate purpose of the sale of Trans Power, unfortunately saddled the industry (including ECNZ itself) with longer-term intractable issues associated with the high valuation. The power companies and major electricity users had wanted a lower valuation that would lead to reduced transmission charges.

Although officials and Ministers appeared to favour club ownership, the will to make a decision was lacking. A second target date of October 1991 had to be postponed, and then public and National caucus anti-privatisation sentiment began to undermine plans for club ownership. Richardson, aided by McTigue, increasingly had to push club ownership on a reluctant Cabinet. The political environment suddenly shifted in early 1993 with the replacement of McTigue as

Minister by Wyatt Creech, and club ownership was discarded in favour of a Crown-owned company as privatisation advocates lost out in Cabinet.

Trans Power meanwhile introduced a policy of customer service to transform itself from an 'inward-looking engineering company to an outward-looking company which is driven by both the generation and supply industry'.[17] ECNZ realised that it was going to have to initiate the separation of transmission and energy charges itself if the developing deadlock was to be broken.

In order to prepare for the anticipated changes, in July 1992 ECNZ introduced internal competition between groups of power stations to establish a merit order of stations ranked in terms of cost for use by Trans Power. ECNZ, Trans Power and the power companies, aided by the Electricity Industry Committee, worked hard to deal with the issue of separating out energy and transmission charges and this was implemented on 1 October 1993. Free and equal access to the national grid was now explicit and formal.

The drafting of contracts for transmission charges proved controversial. The problem was that Trans Power wanted to protect the sunk costs of the grid (past investment that had no value for any other use) by ensuring that users would pay for it even if some of their generation was embedded and thus not routed through the grid. A substantial development of embedded generation would effectively strand Trans Power's assets. While the optimised deprival value methodology took account of this it was not an efficient use of the grid. The government supported Trans Power's position and disagreed with the Commerce Commission's view that the contracts were anti-competitive. But it was clear that lengthy court battles were likely to ensue if Trans Power persisted with its approach, and it abruptly backed down. Meanwhile, no one signed the new contracts.

In January 1994, an electricity summit was convened at which ECNZ, Trans Power, major electricity users and the power companies discussed the issue. To the surprise of some, an industry 'accord' was achieved. The replacement of the existing yearly contracts by long-term tradeable energy contracts was explored. The balance between transmission and energy charges to encourage new generation and energy efficiency was examined and Trans Power agreed to adopt a more flexible approach to contracts with individual companies.

In April 1994 the government finally announced that Trans Power would not be a Crown-owned company after all but an SOE, an organisational form which could be created more easily and was more acceptable politically. Negotiations between ECNZ and the government on the revised terms of sale proceeded rapidly.

Following final deregulation of the retail sector with the removal of franchises in April 1994, Trans Power became a separate SOE on 1 July. Its founding Statement of Corporate Intent was broader than that of other SOEs to ensure that it acted responsibly as a monopoly, and its expected rate of return was set at a low 6.5–8 per cent. Trans Power was valued at $3 billion with $1.8 billion of debt. The Crown thus purchased the equity of Trans Power by paying ECNZ $1.2 billion. All the debt carried across into Trans Power had to be repaid by December 1996. Its key task was therefore to establish its financial credibility for a debt repayment programme.

Trans Power was reorganised, and it successfully refinanced its debt within the period it had been set. It began working on charges reflecting the cost of transmission, but this proved extremely difficult because of the sunk costs. In the end Trans Power offered contracts for up to five years for nominated capacity on a forward basis together with hedges (a form of insurance to protect prices against future fluctuations), in conjunction with nodal pricing (prices at points in the network at which generated electricity enters the system and purchased electricity departs from it). Generators were to be charged the full cost of connection to the grid, and South Island generators were to be charged the full cost of transmission via the Cook Strait cable, which had previously been shared with the power companies.

This offer eventually resulted in the signing of a large number of contracts and the taking up of hedges during 1996, prior to the establishment of the competitive wholesale market. However, the question of full charging for the Cook Strait cable resulted in lengthy negotiations with both ECNZ and Contact Energy. In April 1997, Trans Power and ECNZ concluded an interim compromise agreement on charging for the link.

In the area of broad industry reform, the Wholesale Electricity Market Study (WEMS) that had been formed as a result of the new spirit of co-operation in the industry reported in the latter half of 1992. The report suggested that there was broad consensus on the direction of reform: to institute the market thoroughly, while minimising regulation and political involvement.[18] ECNZ was keen to see reforms go down the competitive market road so that the corporation did not 'drift back into a "pseudo Government department" role'.[19] Since the pricing controversy of 1991 the government had maintained a hidden but effective role in shaping pricing which was to persist until a competitive wholesale market was established late in 1996.

The WEMS group, building on internal ECNZ mechanisms, attempted to find a middle ground that would provide signals for both building new capacity and adopting energy efficient technologies, while protecting consumers, through a combination of contracts and spot-market pricing.

Industry reform moved towards more concrete proposals with the formation of the Wholesale Electricity Market Development Group (WEMDG) in mid-1993. Its study, released in August 1994, concluded that a competitive market would be the best means of achieving new generating capacity.[20] ECNZ's dominance of generation was considered 'a leading obstacle' to its development. The report covered familiar territory in recommending a combination of long-term contracts with a pool and 'spot' market for wholesale sales, open and neutral access to the grid, and competition between wholesale generators.

Moves were already being made along these lines. In August 1993 the Electricity Market Company (EMCO) had been formed, with representation from power companies and ECNZ, together with independent directors.[21] When it was legally formed as a company ECNZ, the Electricity Supply Association and Trans Power became its joint owners. Initially ECNZ and the power companies, and then Trans Power, provided the new company with considerable financial support. EMCO had the task of first developing and then operating the wholesale pool and spot market from 1 October 1996. With the emergence of the market for wholesale electricity the previous contracts with individual power companies based on secret negotiations and special deals had to be unpacked and replaced by more open commodity-based trading in electricity.

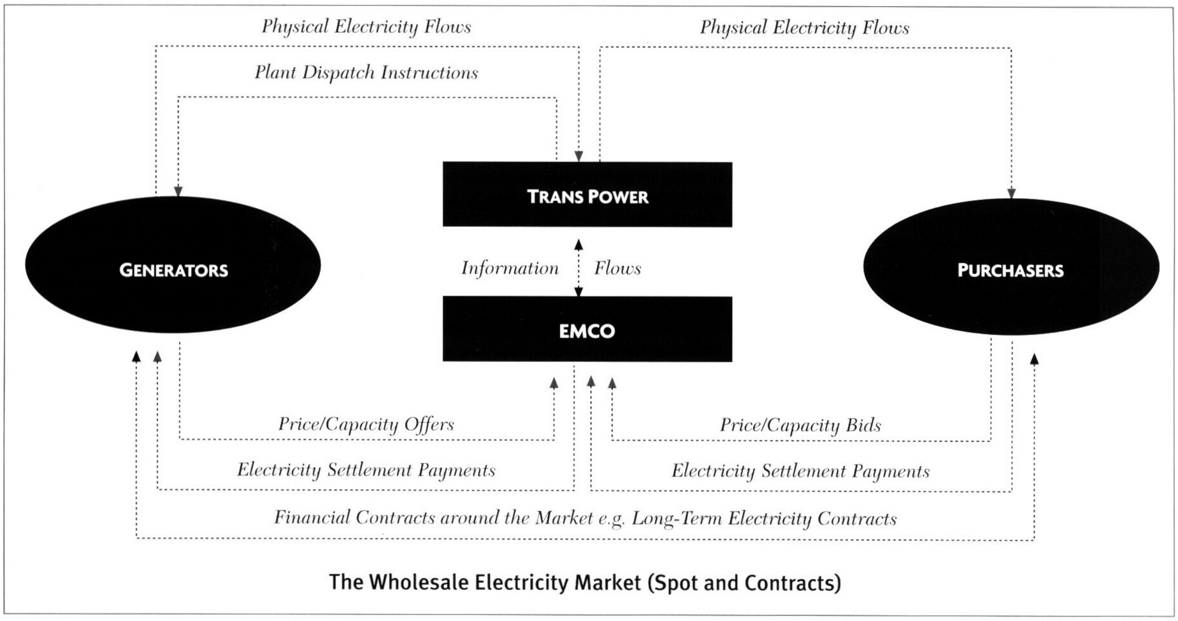
ECNZ meanwhile began to work on developing New Zealand's first long-term financial hedges as a result of the memorandum of understanding of 1995, and in the latter half of 1996 it held five tender rounds for hedge contracts over the next five years. The tenders were successful, with 94 per cent of the available energy sold for $1.4 billion and with prices above the reserve and rising over the five years. The real price trend was downwards, as anticipated by the corporation in an environment of an emerging surplus of generating capacity. A substantial number of 'bilateral' contracts were subsequently negotiated with individual power companies. This experience indicated that competition was going to be tough; downward pressures on prices were severe, and it was difficult to develop value-added customer services in this environment. Nonetheless some progress was made.

Following more than two years' work, the final rules for the wholesale market were set in June 1996, giving Trans Power only a few months to develop its software and systems. The market began to operate in October 1996 as planned; this was a significant milestone for the industry.

The market was designed to co-ordinate generators and purchasers with a minimum of regulation and with spot prices set by the balance of supply and demand. For each half-hour in the day ECNZ and other generators offer energy that they have available from each of their stations at a price they are prepared to generate it. Purchasers make bids according to the price they are prepared to pay to meet the expected demand of end-use customers.

This process takes place several times each day, the first occasion being a day ahead followed by revisions closer to the actual half-hour. The offers are ranked according to price, and stations are 'dispatched' in order of least-cost generation. EMCO announces the 'provisional' price the following morning, but it does not become 'final' for up to a month. This price is known as the 'spot price' which is defined by the offer price of the most expensive generation required to meet the demand for that half-hour. In practice however, prices are more complex than this, since they are calculated for the more than 200 nodes in the transmission system for each half-hour. Alongside this process, to protect themselves from fluctuations in the spot price, purchasers and generators may enter into the financial hedge contracts discussed above.

The competitive market experienced remarkably few teething problems, given the complexity of the system. It was found that in the early days of


Physical Electricity Flows
Physical Electricity Flows
Plant Dispatch Instructions
TRANS POWER
GENERATORS
Information
Flows
PURCHASERS
EMCO
Price/Capacity Offers
Price/Capacity Bids
Electricity Settlement Payments
Electricity Settlement Payments
Financial Contracts around the Market e.g. Long-Term Electricity Contracts
The Wholesale Electricity Market (Spot and Contracts)

The wholesale electricity market.
ECNZ and the competitive wholesale electricity market,
ECNZ Information Sheet, October 1996.

October in practice sellers and buyers did not bid realistically 24 hours ahead, and that the price established closer to the time fluctuated wildly from market forecasts. There were initial concerns over the quality of data supplied by both Trans Power and market participants. At that time, commentators also questioned how stable the process was and how closely the electricity market model matched what was happening in power system. The fluctuations were much reduced, however, when the final prices for the month of October were recalculated, and the system soon settled down.

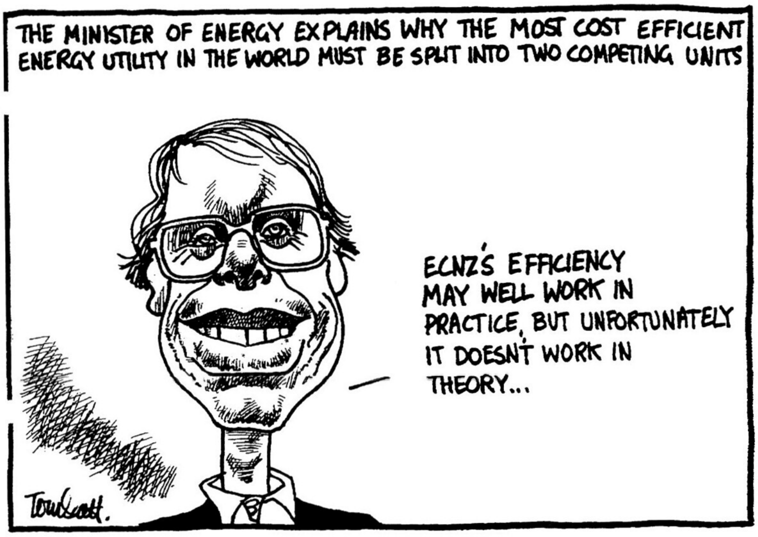
Creation of a second SOE generator

The WEMDG study also set the agenda for renewed consideration of a break-up of ECNZ by proposing a number of options, ranging from a core SOE with 70 per cent of generating capacity together with two smaller SOEs to up to seven competing generators, as well as a leasing option. The study concluded that leasing generating capacity was the only workable option because of the impracticability of having competing SOEs, and that any break-up should proceed cautiously and in an incremental fashion.

ECNZ was not happy with the break-up proposals, and reportedly fought an eleventh-hour battle to prevent being broken into three generators, as was apparently favoured by the controversial unpublished report. WEMDG was also believed to favour privatisation of one or both of the smaller SOEs that would be created by such a split. The release of the final report was delayed while the issue was sorted out. Bolger reportedly backed away from the radical break-up proposal, which he believed was not politically acceptable and could reduce dividends at a time when debt repayment by the government was paramount. Cushing, Chairman of ECNZ, argued publicly that a split would lead to higher prices and that leasing would be both risky and unnecessary.

The published report did not explicitly recommend a break-up into three generators, but it did propose some draconian constraints — that ECNZ should lease progressively 40 per cent of its plant to other operators over a period of five years, and that 95 per cent of its electricity (diminishing to 80 per cent as leasing took place) should be sold on long-term contracts. Moreover, ECNZ should not build the next major station; the proposed Taranaki combined-cycle project together with gas for the plant should be sold; and over the next ten years ECNZ should be restricted to 50 per cent of new capacity built, with no cross-subsidy for electricity from such new capacity. Constraints of this type were to be adopted when part of ECNZ was split off in 1996.

Government officials rejected the leasing concept put forward by WEMDG and continued to work towards a break-up of ECNZ. Stations


THE MINISTER OF ENERGY EXPLAINS WHY THE MOST COST EFFICIENT ENERGY UTILITY IN THE WORLD MUST BE SPLIT INTO TWO COMPETING UNITS
ECNZ'S EFFICIENCY MAY WELL WORK IN PRACTICE, BUT UNFORTUNATELY IT DOESN'T WORK IN THEORY...
Tom Scott.

As the plans to split up ECNZ reached the public, many questioned the need for this.
Tom Scott, *Waikato Times*, 9 March 1995.

generating at the margin (expensive thermal stations) were of crucial concern. This meant that splitting off thermal stations and competition between Huntly and New Plymouth were central. Divesting ECNZ of the Taranaki combined-cycle package was largely taken for granted.

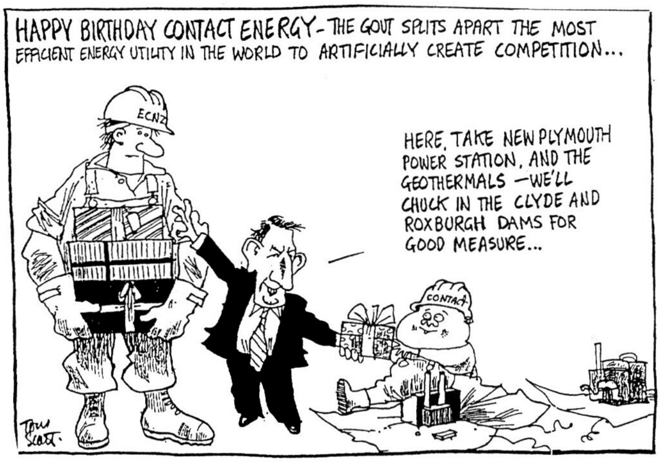
In late 1994 officials recommended a substantial break-up combined with constraints as outlined above. The smaller regional hydro stations were to be sold off. In January 1995 Ministers and ECNZ met on the issue, with the latter unsuccessfully advocating the creation of only one SOE to take over the Taranaki thermal stations and geothermal generation, and that no constraints be placed upon itself. The government's proposal firmed up as a new SOE covering all the thermal stations (apart from Huntly and Marsden), plus the geothermal and the two Clutha hydro stations.

Although officials continued to argue for a three-way split, Bolger was reluctant and wanted a guarantee that prices would not rise as a result. The public attitude to breaking up ECNZ was distinctly unfavourable, with a wide range of groups under the banner of Consumer Coalition 93 expressing their opposition. Wellington's *Evening Post* asked: 'is it beyond us to keep ECNZ intact, restrain its dominance and set up a wholesale market in which competitors can establish new power stations confident in the knowledge they can sell their output for an economic return?'[22] But for proponents of a free market, a break-up was essential. Bolger, always the pragmatist, went cold on the proposal, while Cushing fought a last-ditch battle to retain a unitary ECNZ.

After the proposal had been before Cabinet for some months, the government finally gave approval in principle to a two-way split in June 1995. A memorandum of understanding to this end was signed on 8 June. In addition, the eight smaller regional hydro stations were to be sold off to regional power companies or Maori interests, and the rights to the Taranaki combined-cycle station were also to be sold. Neither ECNZ nor the new SOE, Contact Energy, would have an obligation to supply outside their contracts following the split, but ECNZ was burdened by substantial constraints. The corporation was to be restricted in its activities until its market share had fallen from 60 per cent to 45 per cent of capacity. To ensure that effective competition was created in the spot market, ECNZ had to offer 87 per cent of its capacity by means of long-term hedge contracts in the first year, falling to 30 per cent in the fifth year. It would not be allowed to build more than 50 per cent of any new capacity (apart from cogeneration or renewable sources such as windpower), it was required to ring-fence any additional capacity to prevent cross-subsidisation, and it (like the new SOE) was barred from the retail energy sector.

Contact Energy would operate the New Plymouth, Stratford, Whirinaki and Otahuhu thermal stations, the geothermal stations of Wairakei and Ohaaki, and the two Clutha hydro stations of Roxburgh and Clyde, together with

The Minister of Finance, Bill Birch, hands power stations over to Contact Energy
Tom Scott, *Waikato Times*, 1 February 1996.


HAPPY BIRTHDAY CONTACT ENERGY - THE GOVT SPLITS APART THE MOST EFFICIENT ENERGY UTILITY IN THE WORLD TO ARTIFICIALLY CREATE COMPETITION...
ECNZ
HERE, TAKE NEW PLYMOUTH POWER STATION, AND THE GEOTHERMALS —WE'LL CHUCK IN THE CLYDE AND ROXBURGH DAMS FOR GOOD MEASURE...
CONTACT
Tom Scott.

Maui gas and development sites. It would own \$1.6 billion in assets, comprising 29 per cent of the generating capacity and 22 per cent of annual energy production. Until the competitive wholesale market was established in October 1996, Contact would sell electricity through ECNZ.

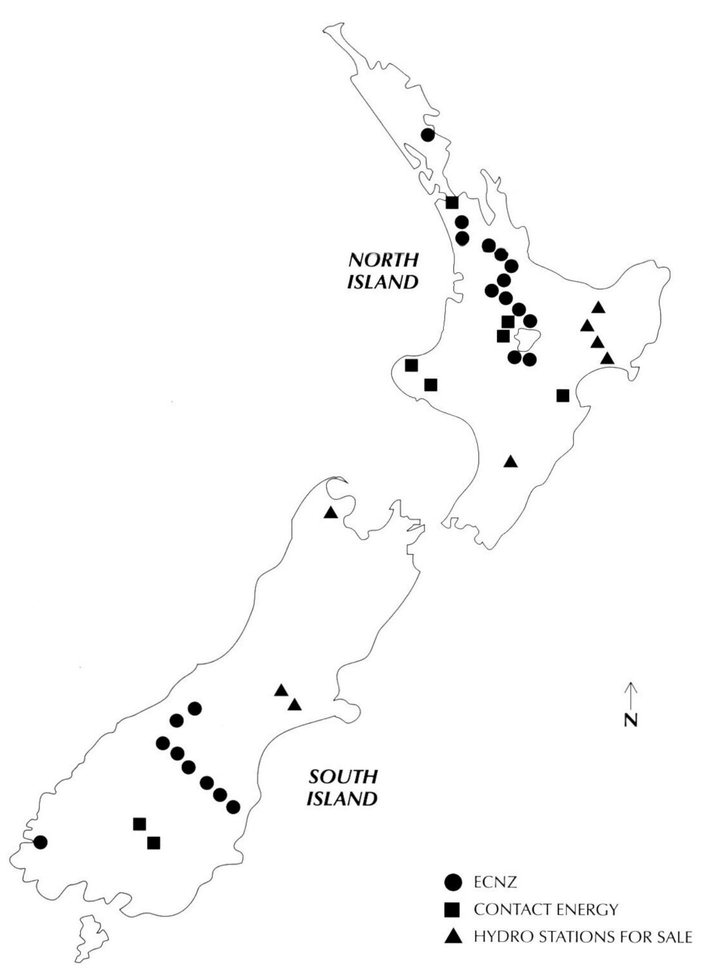
The split took place on 1 February 1996 as planned. Some complicated financial transactions were necessary. ECNZ was paid \$1.592 billion for Contact's assets, of which \$1.173 billion was paid to the government in the form of a special dividend and \$419 million was used to pay off debt.

ECNZ had thus managed to limit its loss of assets for the meantime, but it was clear that the issue of a further break-up would soon reappear. Cushing indicated that ECNZ would compete vigorously with Contact, within the constraints that had been set.

Final break-up

From the end of 1996, following its first MMP election, New Zealand was governed by a coalition between National and the New Zealand First Party which agreed that certain 'strategic' assets, including ECNZ, Contact Energy and Trans Power, should remain in public hands. Thus Bolger's 1993 pledge not to privatise ECNZ was cemented by a formal agreement between the governing parties. This focused the attention of reformers on the possibility of further break-up, consideration of which was also encouraged by a perception amongst politicians and others that prices had not fallen as much as had been expected with the formation of Contact and the wholesale market. ECNZ was frustrated at the constraints placed upon it by the two-way split.

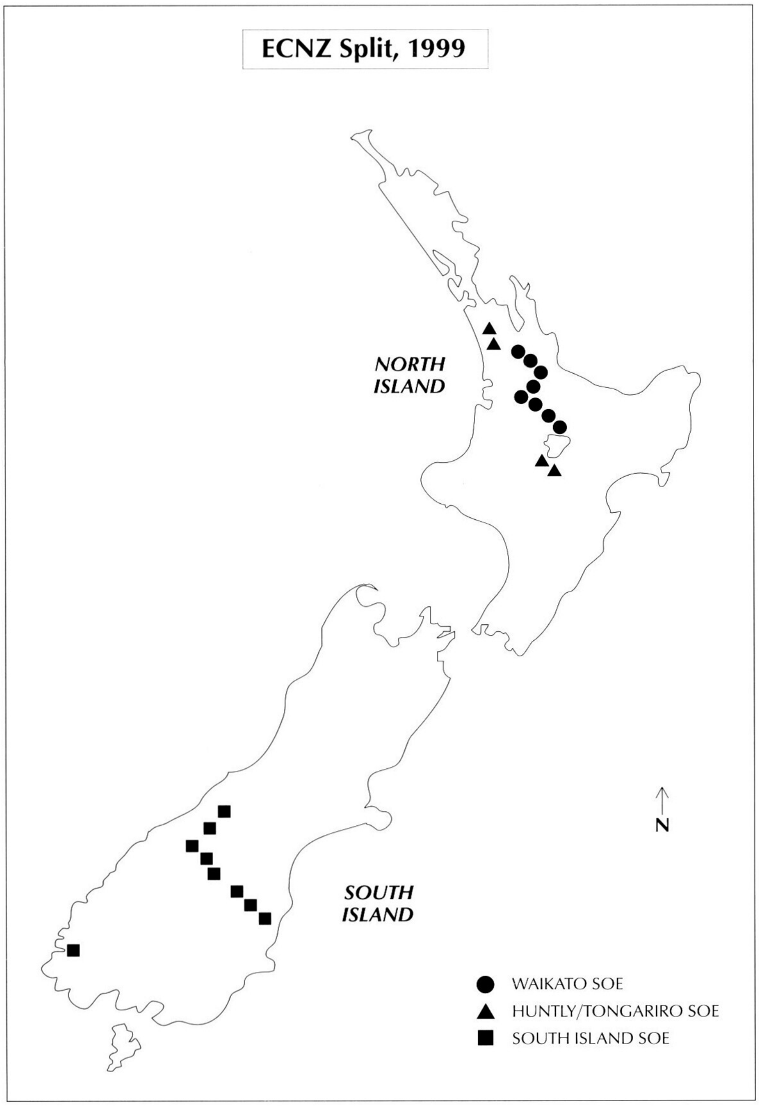
The State Generating System and the Split of 1996



When the government announced a review of break-up options in the June 1997 Budget it appeared that the corporation was almost certain to be split again. Submissions to an officials' committee convened to consider the issue overwhelmingly favoured a further break-up.[23] Max Bradford, the Minister of Energy, indicated that he was determined to reform generation and split the lines and energy retail businesses; he expected that generators would be able to operate as energy traders. ECNZ continued to oppose another break-up. It believed that the review was being made too soon, and that the memorandum of understanding had not been fully implemented. That competition already existed was demonstrated by declining electricity prices, ECNZ's decreasing share of the market and the emergence of new generators. The corporation questioned whether a further break-up would benefit consumers.

When Jenny Shipley replaced Bolger as Prime Minister in November 1997, asset sales and increased competition became more important to the government. Bradford hoped to clinch a split by Christmas, but New Zealand First was concerned that this would prepare the ground for asset sales.

ECNZ now went on the offensive. Cushing suggested that ECNZ should be partly privatised instead through the sale of 40 per cent of the corporation in a public float that would preserve the value of assets and retain control of the 'strategic' asset in public hands. Chief Executive



ECNZ Split, 1999

Frow presented detailed ECNZ figures on the costs of a three-way split which included loss of value to the shareholder, risk to security of supply and harmful environmental effects.

After a delay of some months, during which some Ministers remained unconvinced by officials' arguments, the government announced on 7 April 1998 that it had decided to break ECNZ up into three parts and to separate the line and energy businesses of power companies.[24] There would be a North Island hydro group comprising the eight Waikato stations, with 13 per cent of total national capacity; another North Island group consisting of Huntly and the Te Awamutu cogeneration thermal station, and the Tongariro stations of Tokaanu and Rangipo, with 17 per cent of capacity; and a South Island group of the eight Waitaki hydro stations and Manapouri, with 30 per cent of capacity. (The remainder comprised Contact Energy with 27 per cent and other generators with 13 per cent of capacity.)

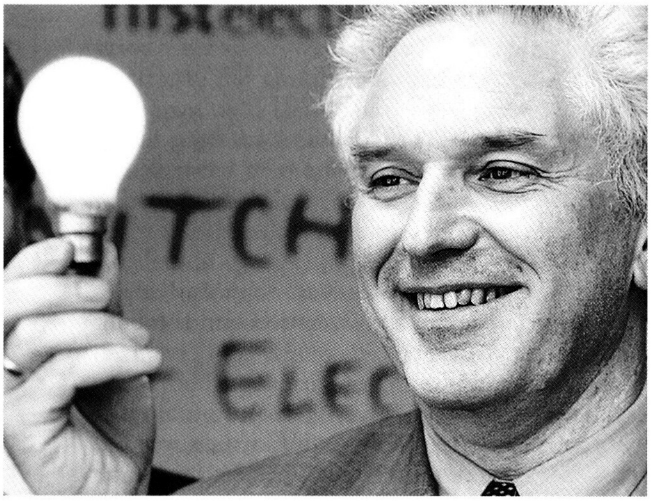
An Electricity Reform Transition Unit (ERTU) was appointed to plan the implementation of the break-up. The supporting legislation was rushed through in July 1998. ERTU reported in September that the split was achievable provided agreements on transmission were reached (this acknowledged the difficulty that ECNZ had had in negotiating an agreement with Trans Power in 1997 for use of the Cook Strait cable).[25] Trans Power indicated that it would post its terms for the three SOEs independently.

ERTU assessed that the South Island SOE's assets would be worth $1,943 million, the Waikato SOE's $729 million and the Huntly/Tongariro SOE's $432 million. Each would be commercially viable and able to compete effectively, but the Huntly/Tongariro SOE would be in a weaker position than the other two, and so should be allocated minimal debt.

The Huntly/Tongariro SOE would hold other gas and coal contracts and the interest in the Kupe field, together with cogeneration at Kinleith and other cogeneration opportunities. The Waikato SOE would hold the overseas business development projects (in Indonesia, Sri Lanka and Fiji), the new retail energy company of First Electric, and Mokai, while the South Island SOE would supply Comalco and hold all current windpower developments and any retail activities acquired prior to the split, in addition to the research and development projects (involving ceramic fuel cells and 'superlink' — low temperature superconducting). The regional hydro stations which remained unsold one year after the break-up date would be allocated amongst the three SOEs.

With the collapse of the coalition government in August 1998 the issues of asset sales and privatisation returned to the political agenda. At the end of September the government announced that it would investigate a sale of Contact Energy, preferably by public float. Cushing, in releasing ECNZ's 1998 annual report in October, again suggested that the government could realise part of ECNZ's assets through a public float of 40 per cent of the company instead of a split. Bradford rejected this.

Once the government has accepted the ERTU report, the Transition Unit will provide final certification and oversee Interim Development



'Mr Bradford is all aglow after signing on with First Electric'. The Minister of Energy, Max Bradford, switches his domestic electricity account to ECNZ's subsidiary retail company First Electric on its launch in October 1998.
Evening Post, 22 October 1998.

Groups for each of the new SOEs. Subject to a final decision in December, establishment processes will be implemented for the SOEs, sale and purchase agreements will be entered into, staff will be appointed, and the new organisations will prepare themselves to commence operations in April 1999.

With the separation of retail line and energy businesses the restriction on retail involvement by ECNZ and Contact Energy was lifted. Both soon moved in this direction, as ECNZ had long wished to do but had been frustrated by political resistance. Many power companies have decided to divest themselves of the energy component of their businesses, preferring to retain the lower-risk line operations.

Contact Energy moved quickly, announcing in August that it would commence retailing in the key market of Auckland and also establishing sales teams in Wellington and Christchurch. The company also purchased a number of retail energy businesses. In October, the newly formed First Electric (a subsidiary of ECNZ) announced that it too would compete vigorously for retail customers by offering lower-priced electricity in urban centres in which lived nearly half of New Zealand's population. On 1 November ECNZ bought Northpower's energy business supplying 45,000 customers.

With Contact Energy being prepared for sale, three new SOE generators being created, and an increasing number of other generators competing to sell electricity, the shape of New Zealand's electricity industry has been irrevocably altered. Consumers are likely to enjoy low electricity prices in the future, as they have done in the past, but the means of achieving this have shifted emphatically from a state-determined unitary system for providing generation and setting prices to a mixed system of generation and market-determined prices. ECNZ — which has dramatically improved the efficiency of both its power stations and its organisation, and has reduced the real price of wholesale electricity substantially -- is able to hand over the state's generating assets in excellent condition for the reshaped electricity industry of the future.

CONCLUSION

Once the pioneering days of the nineteenth century were over, the state assumed a pivotal role in generation which it has retained up to the present day. The government monopoly over generation and the government-set bulk tariff have until recently characterised the electricity industry in New Zealand. Much of this history documents the expansion of state generation. It is worth reflecting briefly on its context and implications.

The first major initiatives in the generation of electricity came in 1886 at the quartz gold mine at Bullendale, and in 1888 at Reefton in the form of a private company set up to generate and supply electricity to the public. The following year a company lit Wellington's streets, and in 1891 legislation was passed which allowed private enterprise to light up three of New Zealand's four major cities. That only in Wellington was this taken advantage of is less important than the fact that the bills were passed through Parliament. In the first years of the twentieth century Dunedin built its own municipal power station at Waipori and other smaller local authorities began to install their own plants.

By this time the government was almost ready to intervene more directly in the emerging electricity industry, having initially entered the field of generation at the turn of the century in order to light the tourist town of Rotorua. It had already regulated the generation and supply of electricity by controlling both water rights and the erection of electric lines for public supply.

The threat posed by the proposed construction by private enterprise of a station at Huka Falls on the Waikato River stirred the government into action. The Water-power Act of 1903 and Hay's and Hancock's surveys of 1904 were the prelude to a sustained and co-ordinated scheme of development of New Zealand's hydro-electric resources that was to be articulated by Evan Parry. The state was to develop these resources to the benefit of the nation and to assume the central role in both the generation and the bulk supply of electricity.

Was this an unfolding of the inevitable? Some have argued that the government's centrality in the development of the infrastructure and economy of this country was a form of pragmatic 'state socialism'; others that only the state had the capacity and resources to undertake large projects; and still others that the state's role was to prevent private sector monopoly. It could also be argued that, especially in the sphere of electricity generation, the government was determined to ensure its control over crucial natural resources, in this case water. The purpose of the late nineteenth century legislation was to maintain control over water rights and the use of water to generate hydro-electric power. The technological developments at the turn of the century that enabled large-scale hydro-electric generation and the transmission of high-voltage AC power over long distances put the seal on state provision. Whatever the genesis of state control, it rapidly was to become a reality in the twentieth century.

Parry was the primary promoter of this vision, while his successors Birks and Kissel followed up with detailed plans for its realisation through the extension of reticulation and the creation of load.

From the beginning, with the Coleridge scheme, the provision of a service was considered crucial and profitability took second place. Parry's goal was to pay the working expenses of the plant from revenue, and this was quickly achieved. The government's aim was to extend the supply of cheap electricity to the bulk of the population, both urban and rural, as soon as possible. The power board structure was to achieve this by means of an effective subsidy from urban to rural areas, which was built into the system.

In line with the government's goal of extending supply as far as possible, growth in demand was encouraged by keeping prices low, and additional capacity continued to be developed to match that growth. New projects were planned on the basis of unrestricted demand and declining real prices.

The notion of confining demand through the price mechanism was rejected. Indeed the price of electricity fell considerably in both nominal and real terms until 1950, and the real price continued to fall until the mid-1970s. This long-term trend has persisted to the present day as a result of the reform of the electricity industry. The wholesale price, in particular, has continued to decline in the last decade.

The history of the bulk-supply tariff also tells us much about the thinking of the day, how it changed and where we are today. Once the principle of government monopoly over generation had been established early in the twentieth century, the focal point of changes in ways of thinking shifted to the bulk-supply tariff — the system the government adopted for charging supply authorities for their bulk electricity. We can identify these changing philosophies by looking at the changes in the structure of the bulk tariff, from one based on maximum demand, to the introduction of a capital levy, to the emergence of an element of the tariff based on energy used, and to a fully commercial range of tariffs not set by the government.

A standard stepped-rate tariff based on quarterly maximum demand, with the rate per kilowatt reduced for additional blocks of power, was applied across the country from the 1920s onwards. This simple but durable tariff, which lasted virtually unchanged until 1957, reflected a dependence upon hydro-electric power and a need at that time both to create and to diversify load.

By the late 1940s pressures for change were building up. The enormous post-war hydro-electric construction programme made tremendous demands on capital, while the continuing power shortages increased operating costs because of the need to use expensive coal-fired stations and to purchase power from other plants. However, the five-year contract with supply authorities signed in 1948 did not resolve the situation.

In 1952, for the first time, it was suggested (by Treasury) that a portion of capital expenditure, perhaps a quarter, should be funded from revenue, and also that the maximum-demand type of tariff should be replaced by a two-part tariff comprising both an energy and a demand charge. However, Davenport and the department resisted both ideas at that time.

Treasury again raised the issue of a substantial capital contribution from revenue in 1954, and by 1956 Davenport accepted the need for this. In 1957 a new tariff, which involved a flat charge per kilowatt of maximum demand, was struck. At the same time an amended State Supply of Electrical Energy Act introduced an additional 25 per cent levy on the bulk tariff to contribute to capital requirements. However, the election of a Labour government and its desire to reduce prices to domestic consumers meant that application of the 1957 Act, including imposition of the levy, was postponed until after the government changed again in 1960. The levy was imposed in 1961 with a new contract that was to continue until 1967.

It was not long before further changes were contemplated. These reflected the increasing role of thermal plant and the diminishing importance of peak load as load diversified towards industry. Mackenzie, the new General Manager in the mid-1960s, began to think in terms of a two-part tariff based on both energy and demand. The current tariff was not funding the desired proportion of capital requirements at a time when a great deal of capital expenditure was planned for the following decade.

By now the traditional dominance of hydro-electric power was being threatened by thermal generation. A component of the tariff that related to actual energy consumed was a logical correlate of this change, as it would relate better to operating costs, whereas the traditional tariff based on maximum demand related more to capital costs and was thus more suited to a hydro-electric system. The State Supply of Electrical Energy Act was also amended in 1965 to empower the Minister to raise the levy to a maximum of 50 per cent because of the need for capital for construction works. In 1967 a five-year contract was drawn up that combined an energy charge and a single annual winter peak-demand charge in a ratio of one to two; later that year an economic recession caused the government to impose the full 50 per cent levy.

Subsequently, in spite of considerable pressure to have contracts negotiated more frequently in an environment of unstable prices and rapid economic change, there was no fundamental alteration in the tariff until 1976. The Labour government elected in 1972 was firmly committed not to increase the price of electricity. As a result the real price of electricity fell considerably at a time of gathering inflation.

Although in the latter 1970s the National government began to consider a radical shift in pricing policy, there was little change in the tariff apart from increases to restore the balance and counter inflation. In 1976 a new tariff raised the price by 60 per cent and the ratio of energy to demand became one to one. A further 40 per cent increase was imposed the following year. In 1979 the tariff was again increased by 60 per cent, but in subsequent years increases were below the rate of inflation and the real price of electricity dropped substantially to well below the cost of supply. The structure of the tariff remained the same.

By the 1980s, however, with the emergence of a philosophy of energy conservation and an end to spiralling demand, people began to consider that electricity was too cheap and argued that it failed to reflect the real cost of its production. It was believed that there should be a coherent energy policy, including pricing. Prices should more accurately reflect the real costs involved and also give a reasonable return on investment. Now that there was surplus capacity, planning should be directed towards efficient use rather than the meeting of extrapolated demand.

Electricity pricing, it was felt, should be oriented more towards the long-run marginal cost of production. This approach involved a fundamental shift from the traditional 'historic average cost' approach that has in the past underpinned the bulk tariff. This traditional philosophy implied that electricity from older and cheaper stations should not be charged at the marginal cost of stations built today.

After two years in which the wage-price freeze prevented any changes, in 1984 a more complex four-part tariff was developed, which, it was argued, more adequately reflected costs in a situation of a flatter daily demand and a levelling of seasonal peaks in comparison with previous times. The ratio of energy to demand components now changed to three to two. These changes were intended to promote 'allocative efficiency' through pricing 'signals'.

Fuller consideration of a fundamental change to the tariff came with the election of a Labour government in 1984 and the implementation of its policy of corporatisation of the state generator. The government-set bulk tariff was abolished and replaced by a commercial pricing strategy with flexible contract options.

The last stages in this evolution of wholesale electricity prices came in the early 1990s, with the separation of energy and transmission charges, the relating of prices more systematically to the cost of production and transmission, and finally, in 1996, with the establishment of a competitive wholesale market and long-term contracts for electricity.

The setting of wholesale prices has been moved out of the political context to be determined by mechanisms of supply and demand, within a framework of increasing competition amongst a range of generators. But the objective of providing electricity to New Zealanders at the lowest possible cost remains: it is the means of doing so that has changed so radically. Market mechanisms have replaced state monopoly.

It might appear that the wheel has turned full circle, in that private enterprise and commercial objectives are once again central to the generation and distribution of electricity, as they were in the nineteenth century. However, the world we live in today bears little resemblance to the pioneering days of electricity in New Zealand.

The contribution of electricity to the infrastructure and economy is so vital that the best means of improving the electricity industry must be found. The post-war ethos of encouraging growth in demand, expanding and investing in capacity without a strong commercial orientation, subsidising rural areas and domestic consumers, and generally not relating the price of electricity to its cost no longer suffices. The remarkable gains of the last decade bear testimony to ECNZ's determination both to maintain the proud tradition of serving New Zealanders and to improve on the past performance of the state generator.

With the split of the corporation into three and the consideration of the sale of Contact Energy, the next chapter in the evolution of the electricity industry is about to begin.

APPENDICES

1 *Organisational developments, 1911–1990*

The first substantial direct government involvement in electricity generation came in 1911 with the appointment of Evan Parry as the first Electrical Engineer in the Public Works Department. Before that, as discussed in Chapters One and Two, the government had already established a crucial role in shaping developments through legislation and regulation. The Public Works Department, established in 1870, was largely responsible for the government's involvement, although the roles of the Mines Department and the Post and Telegraph Department should not be neglected. The contribution made by Lawrence Birks as Engineer-in-charge of the government tourist town of Rotorua from 1906 until 1910 should also be noted.

With Parry, and Birks as Assistant Engineer, the Hydro-electric Branch came into existence. Parry was promoted to Chief Electrical Engineer in 1913 and continued in this position until 1919, when he resigned and returned to England. Birks, who had been promoted to Electrical Engineer in 1913, took over from Parry when he left. In December 1913 the first Station Superintendent, A. R. Blackwood, was appointed for the Lake Coleridge scheme. In 1920 there were six staff at head office in Wellington, 35 in the Christchurch district office for Coleridge, three in Hamilton and six at the Horahora station. In 1921 a district office opened at Hamilton. When Birks died in 1924, F. T. M. Kissel became the branch's Chief Electrical Engineer. In the following decades the Hydro-electric Branch expanded greatly, and became one of the most important parts of the department. Other staff within the Public Works Department were transferred for investigations and field-work as required.

A Mangahao district office for the southern half of the North Island (including Waikaremoana) was opened in 1925. By now Kissel had 41 staff under him, including eighteen engineers, nine engineering cadets, ten draughtsmen and four draughting cadets. There were District Electrical Engineers at Hamilton, Shannon and Christchurch. By 1930 there were Station Superintendents at Lake Coleridge, Mangahao, Arapuni and Tuai, and these stations and Horahora each had five station operators and three shift operators.

In 1943 the Minister of Works, Bob Semple, established a departmental committee to reorganise the Public Works Department in the context of the establishment of a new policy-related Ministry of Works and the incorporation of the Housing Department into the Public Works Department. A crucial issue was whether to establish the Hydro-electric Branch as a separate department. After a long struggle between the Cabinet and various government departments, a decision was made in 1945 to create a new department. This would be responsible for the generation and supply of electricity, including the construction of transmission lines and main substations, and for the planning and both electrical and civil design of projects, with the Public Works Department continuing with construction. (Within a year the Public Works Department merged with the ministry to form a new Ministry of Works.)

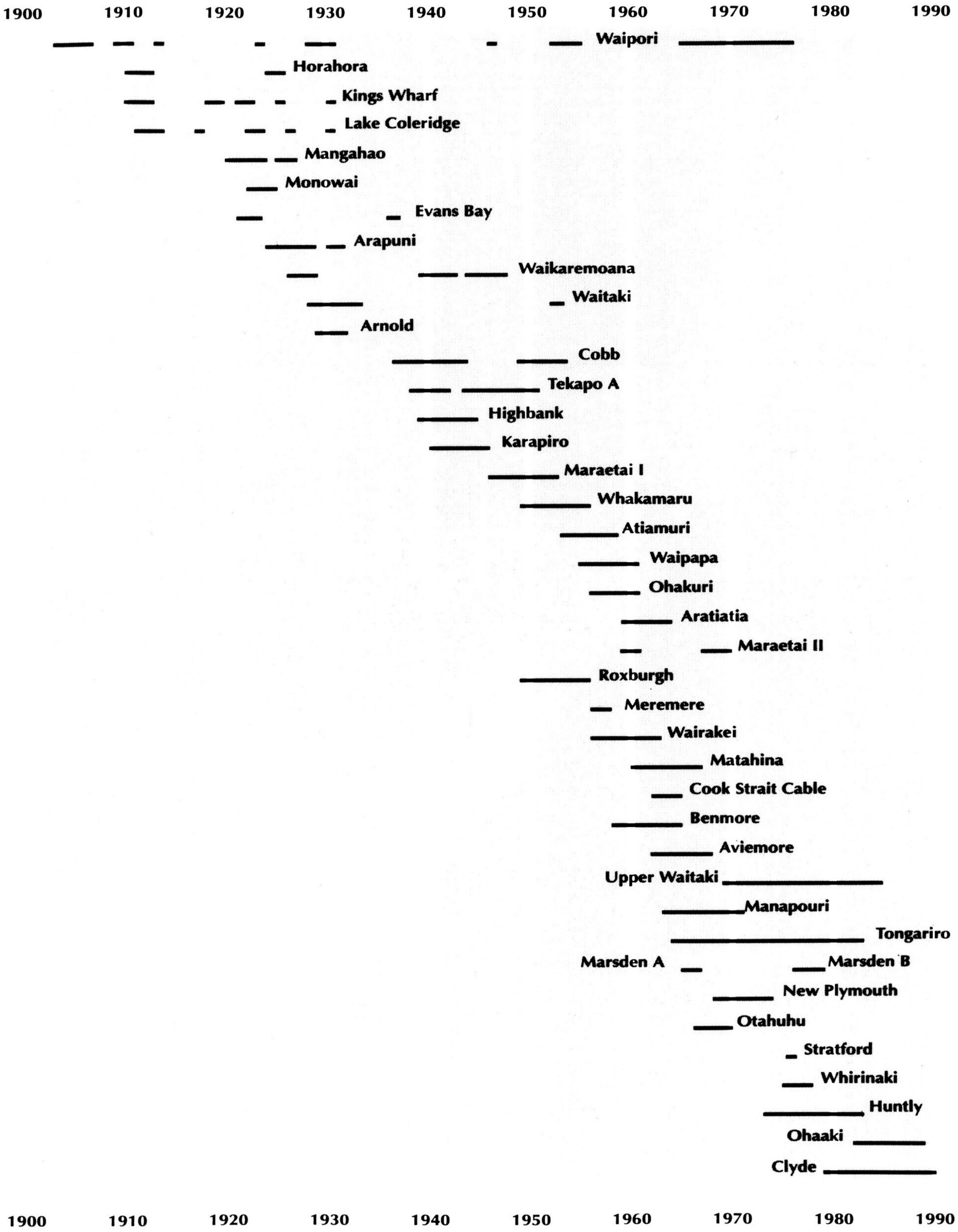
The new organisation, the State Hydro-electric Department, came into existence on 1 April 1946 after the passing of the Electricity Act 1945. Kissel was appointed as its first General Manager, with A. E. Davenport as his Chief Electrical Engineer, while C. W. O. Turner had charge of civil-engineering works. However, the separation of civil-engineering design and construction did not work in practice, and from 1 April 1948 responsibility for the investigation and design of civil-engineering works returned to the Ministry of Works.

Kissel oversaw the first years of the new department. Upon his retirement in 1948, A. E. Davenport took over as General Manager. There was a tremendous expansion in the numbers of staff and engineering graduates in the post-war years as the workload increased dramatically. In 1958, in recognition of the broadening involvement of the department in thermal and geothermal generation, it became the New Zealand Electricity Department. On 1 April 1959 a separate Power Division was established in the Ministry of Works. In 1963 E. B. Mackenzie replaced Davenport as General Manager of the Electricity Department. Mackenzie retired in 1972 and was succeeded by P. W. Blakeley. In 1973 the Ministry of Works became the Ministry of Works and Development.

The oil crisis of the 1970s caused a rethink of energy planning, and emphasised the need for integration and co-ordination of different sources of energy and the importance of conservation and wise use of resources. As a result the department became the Electricity Division of a new Ministry of Energy on 1 April 1978. On Blakeley's retirement in 1979, he was replaced by K. D. McCool, who continued as General Manager of the Electricity Division until 1987.

On 1 April 1987 the Electricity Division became the Electricity Corporation of New Zealand Ltd, a state-owned enterprise. A year later the corporation was divided into four trading units: Electricorp Production, Trans Power New Zealand Ltd, Electricorp Marketing and Power-DesignBuild Group Ltd. In 1988 the Ministry of Works and Development was disestablished and its commercial division, including the Power Engineering Division, became the Works and Development Services Corporation, a state-owned enterprise.

2 Power Stations: dates of construction



3 *Electricity statistics, 1920–1998*

Year Ending March	Total Capacity (MW)	Consumers (thousands)	Circuit Kilometres of Line	Real Retail Price (cents/unit)	GWh Generated per annum	Annual Increase in GWh Generated (%)	
1920	45.8	58.4	n.a	52.78	99.9	n.a	
1921	49.6	73.2	4216	35.60	149.5	49.6	
1922	51.7	88.8	4528	39.40	171.9	15.0	
1923	57.6	106.8	6047	52.40	195.6	13.8	
1924	66.0	124.7	7849	53.28	216.8	10.8	Average increase over period 1920-30 is **22.2%**
1925	81.9	148.7	9672	55.01	253.8	17.1	
1926	127.0	192.4	20038	55.59	346.3	36.4	
1927	138.9	228.3	24095	48.65	452.0	30.5	
1928	146.4	243.8	27454	47.30	523.4	15.8	
1929	175.0	266.3	28574	44.48	594.9	13.7	
1930	254.0	284.2	30777	40.36	709.7	19.0	
1931	224.0	300.8	31594	43.20	759.8	7.3	
1932	191.1	309.4	32584	44.92	787.8	3.7	Average increase over period 1931-35 is **5.3%**
1933	203.4	323.0	33121	42.69	829.3	5.3	
1934	203.7	334.6	33783	41.87	857.5	3.4	
1935	233.8	342.3	34927	39.13	914.1	6.6	
1936	235.4	356.0	36080	37.78	989.3	8.2	
1937	235.5	371.0	37525	33.00	1086.8	9.9	Average increase over period 1936-41 is **12.0%**
1938	279.9	388.6	39271	29.66	1249.8	15.0	
1939	279.9	407.3	41805	27.87	1416.1	13.3	
1940	299.4	426.4	44019	25.42	1633.9	13.3	
1941	338.1	442.2	45342	23.59	1830.2	12.0	
1942	340.8	455.0	46721	21.50	1928.6	5.4	
1943	364.2	460.8	47383	20.35	2036.4	5.6	
1944	414.3	465.3	47618	20.10	2170.2	6.6	Average increase over period 1942-48 is **5.2%**
1945	395.4	473.8	48539	19.67	2273.8	4.8	
1946	433.9	486.2	49520	19.14	2365.0	4.0	
1947	455.9	493.1	50553	18.85	2528.2	6.9	
1948	509.2	511.7	54777	18.05	2599.4	2.8	
1949	586.7	533.4	61647	17.12	2844.4	9.4	
1950	590.0	554.6	65195	17.10	3035.8	6.7	
1951	589.9	576.3	67843	16.07	3096.7	2.0	
1952	616.1	599.5	70180	14.62	3462.3	11.8	
1953	702.0	622.4	73642	14.21	3579.0	3.4	
1954	764.9	643.8	77721	16.86	4029.5	12.6	
1955	864.6	671.3	81551	16.46	4383.2	8.8	
1956	940.2	699.6	85671	15.99	4748.3	8.3	
1957	1205.2	725.9	90101	15.54	4967.4	4.6	Average increase over period 1949-1967 is **8.1%**
1958	1201.0	751.4	94041	14.97	5644.1	13.6	
1959	1360.0	777.5	97423	17.84	5677.4	0.6	
1960	1509.4	802.9	100294	17.08	6360.7	12.0	
1961	1565.8	831.9	104220	16.57	6834.5	7.4	
1962	1814.6	859.7	106612	16.18	7399.3	8.3	
1963	1944.6	884.2	110146	15.92	7951.3	7.5	
1964	2006.3	912.7	112635	15.33	8963.4	12.7	
1965	2335.8	940.2	115526	14.70	9718.2	8.4	
1966	2522.1	967.1	118704	14.21	10577.6	8.8	
1967	2649.8	992.4	120699	14.07	11316.5	7.0	
1968	2975.5	1014.5	124311	14.40	11604.6	2.5	
1969	3137.5	1080.7	126966	14.79	12185.1	5.0	
1970	3682.7	1086.7	129891	14.00	12925.6	6.1	
1971	3908.6	1109.6	132231	12.92	13705.7	6.0	Average increase over period 1968-77 is **6.4%**
1972	4208.6	1129.4	135898	11.35	15193.7	10.9	
1973	4209.2	1154.0	128605	10.18	17253.5	13.6	
1974	4543.7	1182.5	130685	9.35	18114.4	5.0	
1975	4784.5	1214.9	134121	8.50	18351.7	1.3	
1976	5037.7	1248.9	138146	7.59	20071.2	9.4	
1977	5365.7	1280.2	139958	9.12	20914.2	4.2	
1978	5633.7	1310.0	141899	10.85	21268.5	1.7	
1979	5623.3	1327.5	143986	10.59	21692.8	2.0	
1980	5860.4	1345.3	144632	12.76	21607.2	-0.4	
1981	6018.2	1363.2	147446	12.00	22110.6	2.3	
1982	5826.6	1377.7	148853	11.42	22962.7	3.9	
1983	5819.8	1396.8	150528	11.21	24301.3	5.8	Average increase over period 1978-90 is **2.9%**
1984	6382.3	1417.6	152290	10.51	25854.9	6.4	
1985	6987.9	1436.7	154496	9.98	26764.6	3.5	
1986	7435.1	1462.7	156102	10.51	27017.1	0.9	
1987	7388.7	1488.3	157487	10.43	28160.4	4.2	
1988	7398.5	1509.2	159473	10.25	28686.4	1.9	
1989	7373.0	1528.6	161309	10.31	29457.8	2.7	
1990	7181.9	1547.6	161068	9.84	30157.3	2.4	
1991	7067.5	1581.9	155720	9.39	30857.6	2.3	
1992	7087.9	1599.0	150692	9.46	31905.3	3.4	
1993	8528.6	1607.9	152187	9.62	31248.1	-2.1	Average increase over period 1991-98 is **2.4%**
1994	7708.0	1621.3	152010	9.49	32452.7	3.9	
1995	7924.0	1621.3	145504	9.35	34644.9	6.8	
1996	7681.1	1644.0	145134	9.50	35272.1	1.8	
1997	7899.8	1667.3	150909	9.54	35777.8	1.4	
1998	8248.0	1679.4	151498	n.a	36343.4	1.6	

Source: official electricity statistics, 1920-1998

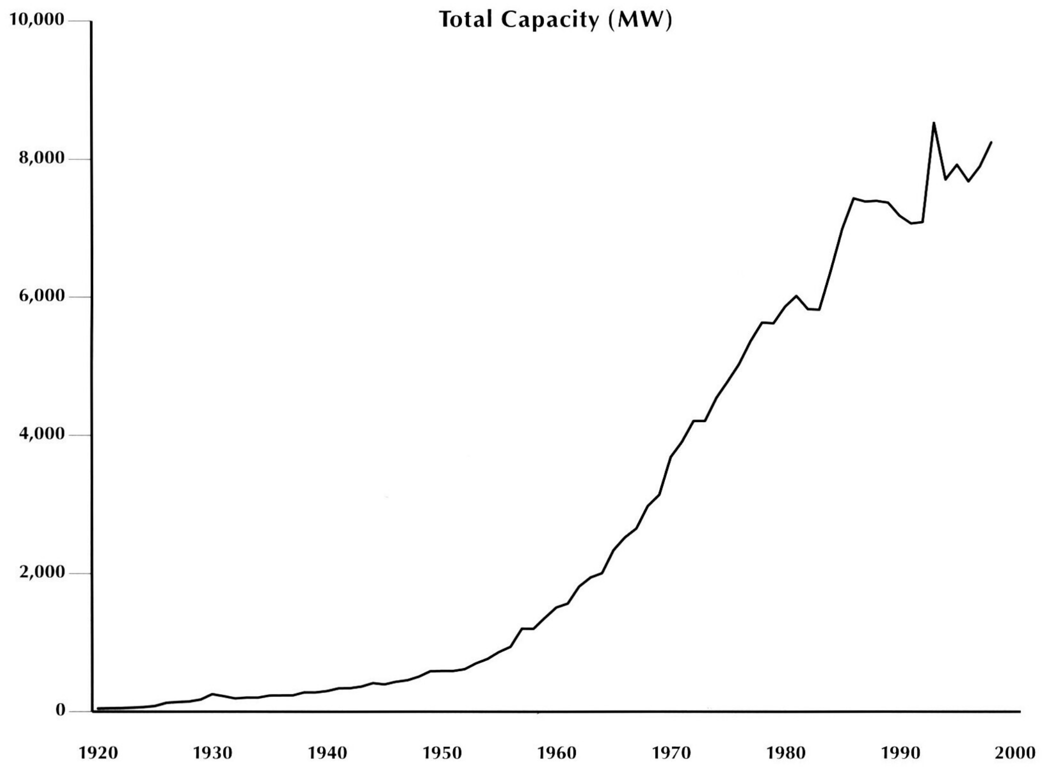
Note 1. Prior to 1973 the length of the line was measured as route miles rather than circuit kilometres. The apparent reduction in length of line between 1972 and 1973 is the result of the changed basis of measurement.

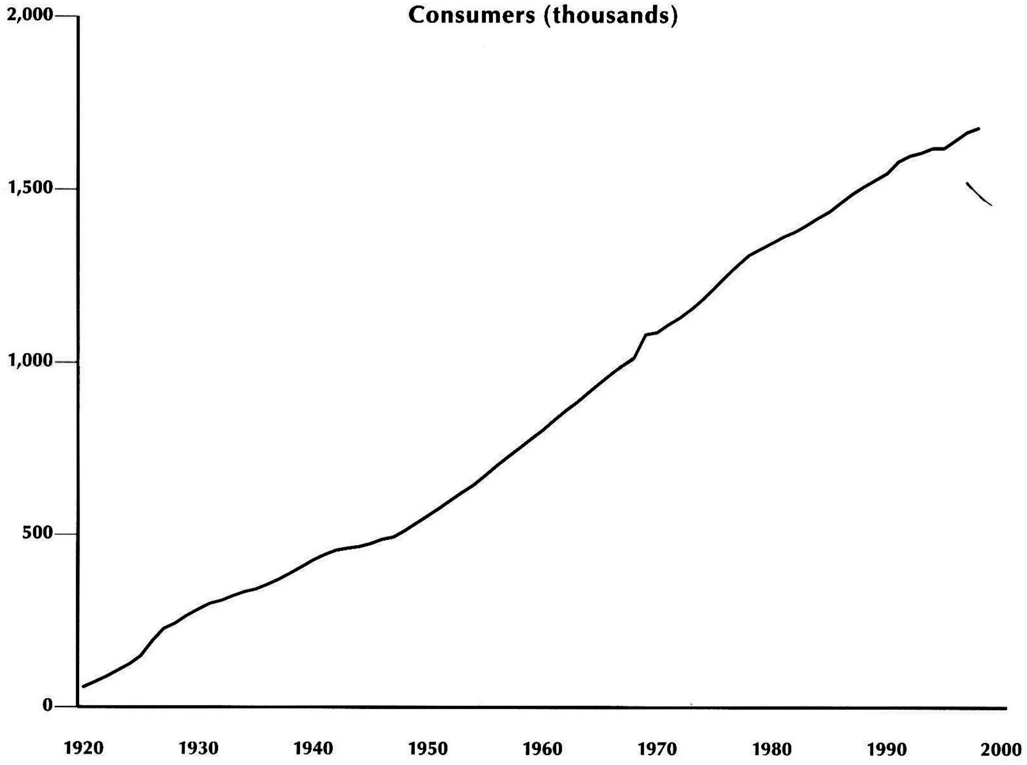
Note 2. Real retail electricity prices. Nominal retail prices of electricity are derived from revenue from sales divided by units sold. Prior to 1933 figures for total revenue have to be used. Using the Consumers Price Index of base December 1993=1000, nominal prices are converted to real prices in year ending March 1998 terms.

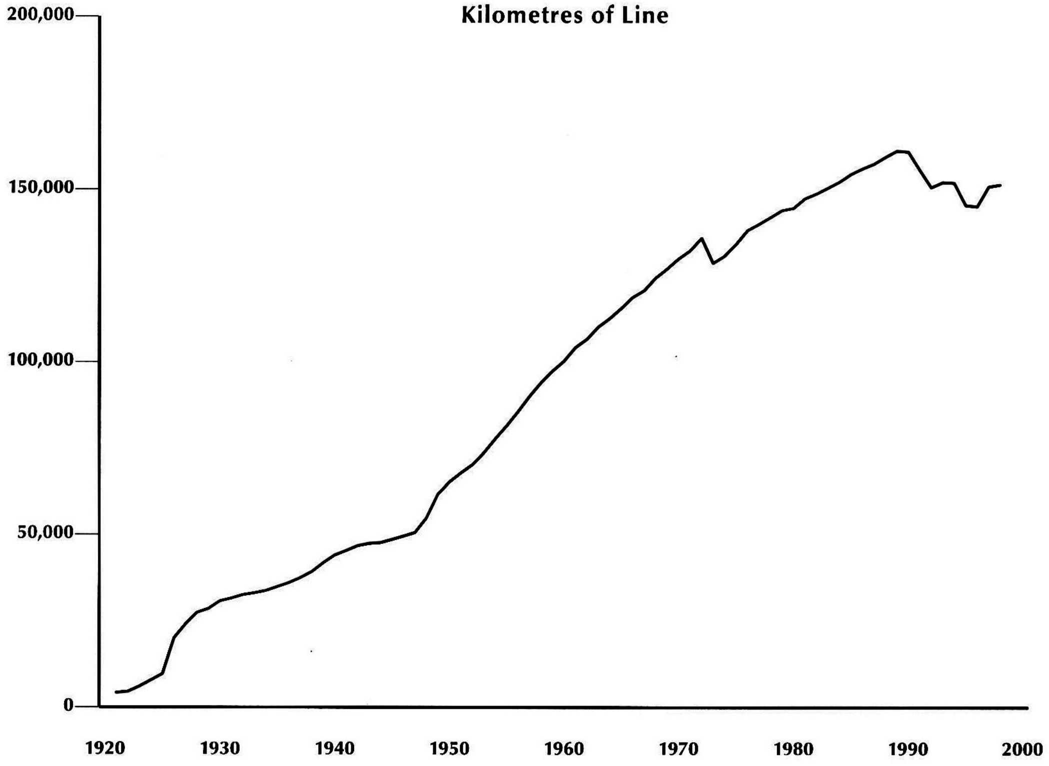
4 *ECNZ, 1988–1998*

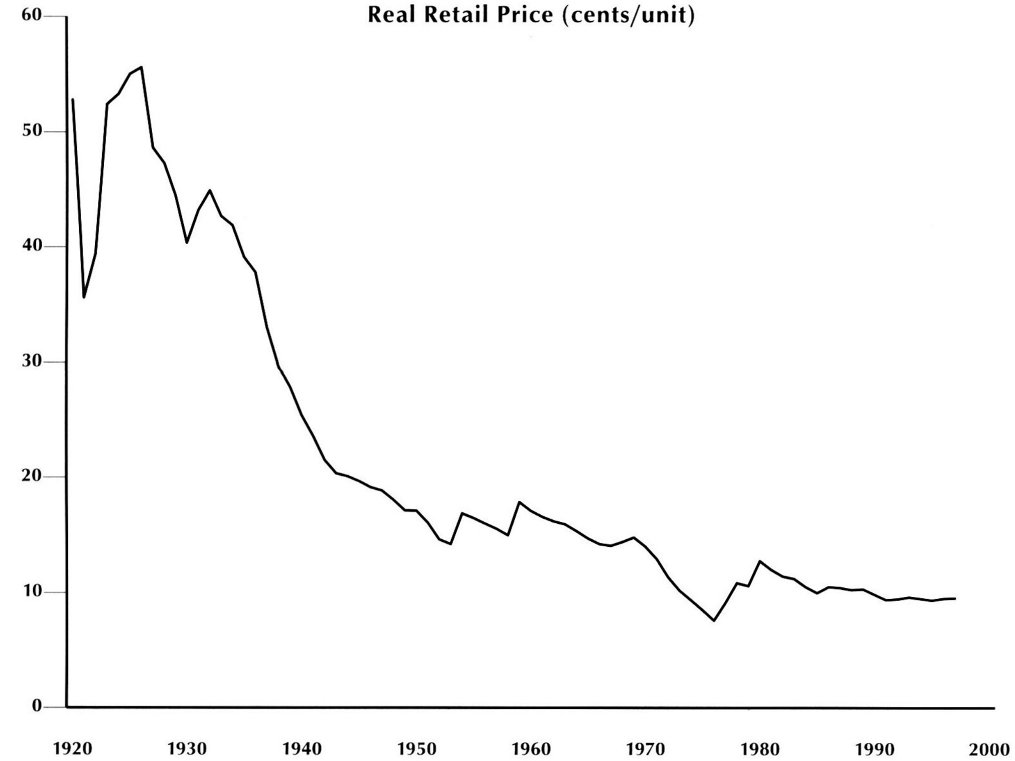
Year Ending March (June from 1994)	Real Wholesale Price (cents/unit)	Real Cost (cents/unit)	Net Profit ($ million)	Return on Equity (%)	Tax	Ordinary Dividends	Special Dividends	Staff Numbers
1988	n.a	2.00	141	4.3	–	108	–	4526
1989	4.82	1.78	373	12.6	81	247	–	3876
1990	4.56	1.80	359	11.7	108	254	–	3690
1991	3.86	1.70	456	14.0	56	314	–	3730
1992	3.82	1.70	449	13.1	78	335	–	3096
1993	3.73	1.87	330	8.6	63	280	–	2861
1994	4.10	1.79	496	10.7	220	390	116	2835
1995	3.89	1.54	386	12.5	196	257	600	1678
1996	3.52	1.44	324	14.1	225	243	1173	1134
1997	3.70	1.55	264	12.8	123	148	158	1090
1998	3.73	1.38	307	14.8	143	68	–	581

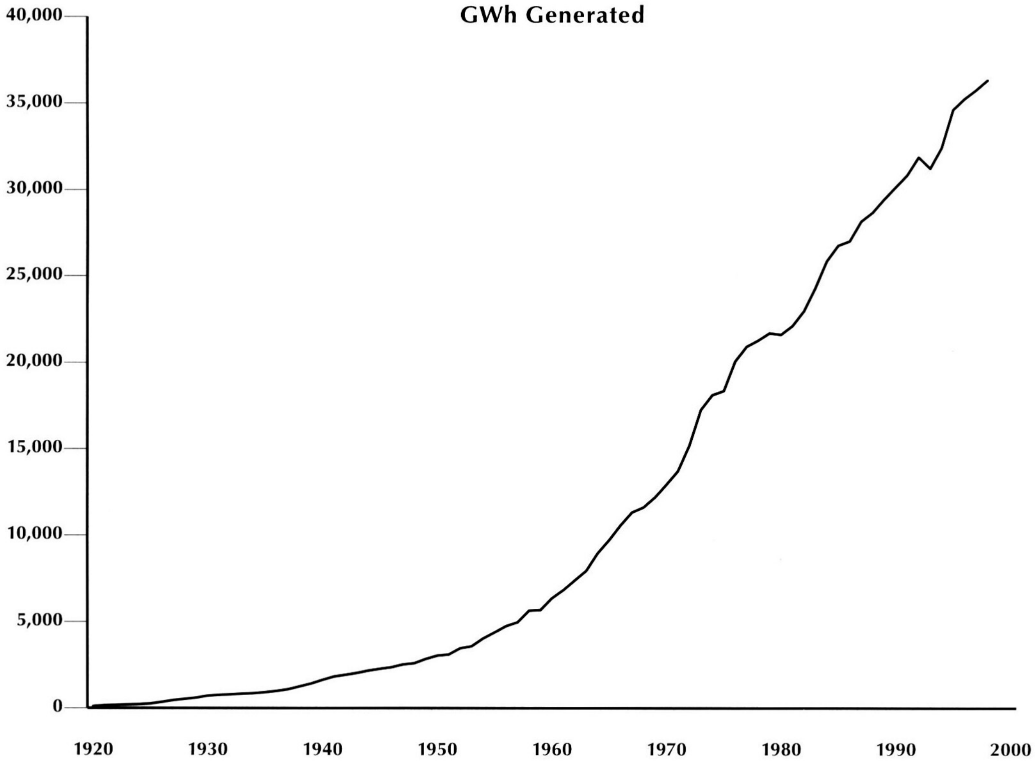
Source: ECNZ Annual Reports. Note that statistics are for March years for the period 1988-1993 and for June years for the period 1994-1998. Real wholesale prices are on a base of 1998 dollars. Real costs are on a base of 1987 dollars and exclude finance and tax. For the period 1988 to 1993 an adjustment has been made to costs to make them consistent with the data from 1994 onwards.




Consumers (thousands)
2,000
1,500
1,000
500
0
1920
1930
1940
1950
1960
1970
1980
1990
2000


Kilometres of Line
200,000
150,000
100,000
50,000
0
1920
1930
1940
1950
1960
1970
1980
1990
2000


Real Retail Price (cents/unit)
60
50
40
30
20
10
0
1920
1930
1940
1950
1960
1970
1980
1990
2000


GWh Generated
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1920
1930
1940
1950
1960
1970
1980
1990
2000

GLOSSARY

AC	alternating current, the direction of which changes cyclically
alternator	an alternating-current generator
ampere	unit of electrical current
arch dam	a thin-walled curved dam dependent on the strength of the arch and solid abutments to secure it against the force of the water acting on it
bar	metric unit of gas or fluid pressure (one bar is the barometric pressure at sea level)
base load	the component of the load in a system that is continuously present over a given period
bulk-supply tariff	the charging structure used by the government for the supply of electricity in bulk to supply authorities
capacity	a measure of the power available from a generating unit, plant or system, expressed in kilowatts or megawatts
cumec	one cubic metre of water per second (the metric measure of flow)
cusec	one cubic foot of water per second (the imperial measure of flow)
DC	direct current, which flows constantly in a single direction
diversion tunnel/channel	a temporary watercourse formed to divert a river around a dam site while the dam is being built
draught tube	a tube leading water away from a turbine into the tailrace
dynamo	a direct-current generator
earth dam	a gravity-type dam, constructed of excavated materials such as clay, silt and rock, with an impermeable core and permeable supporting shoulders
energy	amount of power expended within a given time, measured in units, kWh or GWh, for example
forebay	the area in the immediate vicinity of the penstock intakes
Francis turbine	a hydraulic reaction turbine with fixed runner blades, suitable for medium and low heads
frequency	the rate at which alternating current changes cyclically, measured in Hertz (cycles per second). The standard frequency in New Zealand is 50 Hertz
generator	a machine for generating electrical energy
geothermal station	a power station generating electrical energy from steam produced by natural heat below the earth's surface
gravity dam	a thick dam dependent on its weight to secure it against the force of the water acting on it
GWh	gigawatt-hour = one million units, or 1,000 kilowatt-hours
head	the height of water above the turbines, used as a measure of hydraulic pressure
headrace	a channel leading water to the penstock intakes of a powerhouse

hp	horsepower, an imperial unit of power
intake	the structure leading water into the penstocks
Kaplan turbine	a hydraulic reaction turbine with adjustable pitch runner blades, suitable for a varying low head
kV	kilovolt = 1,000 volts
kW	kilowatt = 1,000 watts
kWh	kilowatt-hour = 1,000 units
load	the demand for power made on a generating unit, plant or system at any one time
load curve	a graph recording the variations in load on a generating plant or system over time
load factor	the relationship between the actual average load on a generating plant or system over a given period, usually a year, and the maximum potentially available, expressed as a percentage
maximum demand	the maximum energy consumed in a half-hour demand period, used for statistical and bulk tariff calculations
MW	megawatt = one million watts, or 1,000 kilowatts
overload	a load greater than the rated capacity of a generating unit, plant or system
peak load	the maximum load on a generating plant or system at a given time
Pelton wheel	a hydraulic impulse turbine suitable for a high head
penstock	a downward-sloping pipe, tunnel or shaft leading water from the intake to the turbines
power	capacity to do work, measured in watts, kW or MW, for example
propeller turbine	a hydraulic reaction turbine with non-adjustable runner blades, suitable for a non-varying low head
psi	pounds per square inch (the imperial unit of gas or fluid pressure)
sluice gate	a sliding gate built into the base of a dam that allows it to drain
spillway	a structure for releasing surplus water from a dam
steam engine	a reciprocating engine driven by steam pressure
suction gas engine	a reciprocating internal-combustion engine that draws fuel gas into its cylinder by suction
surge chamber/tank	an open water reservoir designed to absorb a sudden rise in pressure in a pipeline or penstocks
synchronous condensor	a machine running without load to maintain voltage at the local level by compensating for fluctuating voltages in the wider system
system control	the communication centre in each island from which the operation of the system is monitored and controlled
tailrace	the channel for water leaving the powerhouse
thermal station	a power station generating electrical energy from thermal (i.e. heat) energy by burning coal, gas, oil, etc.
turbo-alternator	a combined steam (or gas) turbine and generator unit
unit	unit of energy = one watt-hour
volt	unit of electrical pressure
water/steam/gas turbine	a machine that converts water/steam/gas pressure into mechanical energy to drive a generator
watt	unit of power = one volt × one ampere

CONVERSION FACTORS

feet to metres	0.3048	tonnes to tons	0.9842
metres to feet	3.281	tons to tonnes	1.0161
miles to kilometres	1.609	watts to horsepower	745.7
kilometres to miles	0.6214	horsepower to watts	0.00134
cumecs to cusecs	35.32	bars to psi	14.5
cusecs to cumecs	0.0283	psi to bars	0.069

Note: The approach to units of measurement in this book has been to adopt those of the period when the project was being built. The head of hydro-electric stations given is the 'static' head and is drawn from the annual departmental statistics, from 1972 for pre-metric measurements and from 1989 for more recent stations. The static head is the difference in height between the usual operating level of the water in the dam or headrace, or at the top of the penstock, and the level of the turbine (as measured by the mean tailrace level). Turbines are of the vertical Francis type, unless specifically noted. The capacity cited is that at the time of installation; in some cases there has been a small change in capacity since. Where possible, figures for the length and height of dams have been drawn from the publication of the New Zealand Society on Large Dams, *Dams in New Zealand*. This gives the length of the crest of the dam, and the height above the bedrock foundations. The schematic drawings are not strictly to scale. Those illustrations not otherwise acknowledged are held by ECNZ.

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Chapter One: Power Pioneers

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19. Herbert, 'Changing pattern of public works settlement', pp. 61–3. There were earlier examples of this on the Napier–Wairoa railway, organised by the union *c.* 1923, and at Otira. The issue was discussed fully at the 1926 NZ Workers' Union conference.
20. Even though the Grand Junction mine closed in the 1920s, the Grand Junction plant continued to generate electricity for the North Island system until July 1931. It was purchased by the government in 1927. In June 1930, because of the problems with Arapuni, a 1,500 kW steam turbine was removed from this plant and relocated at Huntly. The Huntly plant was reactivated during the Second World War before being decommissioned. The Penrose plant, comprising three 1,500 kW diesel engines, was built quickly between December 1927 and June 1928 in response to shortages in Auckland before Arapuni began operating. It was used heavily until Arapuni began generating, and again when Arapuni was taken out of service. The plant was shut down in April 1932 and recommissioned for the winter of 1940 to deal with wartime shortages. It was then used extensively until the early 1950s. The plant was decommissioned and dismantled in July 1952 after a generator main shaft broke and the other two main shafts were found to be beginning to break up.
21. *AJHR*, 1930, D-1C. 'Professor P. G. Hörnell', *NZ Electrical Journal*, 25 January 1939.
22. *AJHR*, 1930, D-1C, p. 9.
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4. Natusch, *Waitaki Dammed*, p. 44.
5. *AJHR*, 1932, D-1, Appendix B, p. 44.
6. NZ Workers' Union, Conference Report, 1934, p. 7.
7. *NZ Electrical Journal*, 25 April 1940.

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2. See Hughes, *Networks of Power*, pp. 370–1.
3. H. W. Scott, 'The electric home', in *The Young New Zealander and New Zealand Woman and Home*, February/March 1926, p. 3.
4. W. T. Doig, *A Survey of Standards of Life of New Zealand Dairy-farmers*, Wellington: Government Printer, 1940, pp. 41–3.
5. *NZ Electrical Journal*, 10 October 1933, p. 38.
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7. 'Shortage of power predicted for South Island', *NZ Electrical Journal*, 10 August 1938.
8. *NZ Electrical Journal*, 25 October 1938, 25 January 1941, 25 June 1943.
9. Electricity Emergency Regulations, 1939, *NZ Gazette*, 1939, vol. 3, p. 2396. For the war period, see the publications in the Department of Internal Affairs' series *The New Zealand People at War*: J. V. T. Baker, *War Economy*, 1965, and N. Taylor, *The Home Front*, 2 vols, 1986.
10. The imposition of import restrictions in 1938 had dramatically reduced imports of electrical appliances and given a virtual monopoly to locally manufactured items.
11. Baker, *War Economy*, pp. 432–3.
12. *AJHR*, 1947, D-4, p. 5.
13. E. B. Mackenzie, 'Forecasting and meeting demands for electric power in New Zealand', *NZ Engineering*, November 1966. *AJHR*, 1950, D-4, p. 5.
14. *Census of Population and Dwellings*, 1945.
15. R. H. Lindsay, 'The supply of electricity to 273 State houses', Electric Supply Authority Engineers' Institute of NZ, *Transactions*, vol. 24, 1954.
16. A. E. Davenport, 'Electric power development in New Zealand', *Evening Post*, 17 April 1973. *NZ Engineering*, 15 July 1973.
17. Electric Supply Authority Engineers' Association, *Proceedings*, vol. 14, 1942–43. Electric Power Boards and Supply Authorities Association, Twentieth Annual Conference Report, 1948. Electric Supply Authorities

Association, Twenty-sixth Annual Conference Report, 1954.

18. *AJHR*, 1958, D-1, p. 10.
19. Farrell, *Power in New Zealand*, p. 33.
20. *AJHR*, 1955, D-4B.
21. Ibid., p. 5.
22. A. E. Davenport, 'The background of New Zealand's power plans', *NZ Electrical Journal*, 25 November 1955. A. E. Davenport, Address to Electrical Supply Authorities Association.
23. *AJHR*, 1958, D-4A.
24. *AJHR*, 1968, D-4.
25. *Evening Post*, 4 November 1972, 13 October 1983. *Timaru Herald*, 15 October 1983. *Who's Who in New Zealand*, 1978. *NZ Engineering*, 15 April 1973, 1 February 1984.
26. *AJHR*, 1964, D-4B, p. 13. The possibility of nuclear-power generation was first introduced explicitly into the power plan in 1968 and maintained until 1977. In the late 1960s staff went overseas to study nuclear power, and various sites on the Firth of Thames, the Kaipara Harbour, in the Wellington region and on Banks Peninsula were investigated. Meanwhile considerable debate as to the merits of nuclear power was emerging by the early 1970s. In 1975, as a result of increased projections of demand, the Power Planning Committee proposed two 600 MW reactors by 1980, but with an election approaching, both major political parties offered public inquiries. In September 1976 the National government appointed a Royal Commission to inquire into nuclear-power generation; this was soon followed by a petition to Parliament with one-third of a million signatures opposing nuclear power. By 1977 slackening demand for electricity and the changed climate of opinion led to the dropping of any proposals. The commission's report of May 1978 reflected these changes, and concluded that there was no need to consider the possibility before the next century.
27. *AJHR*, 1968, D-4A, p. 4.
28. *AJHR*, 1969, D-4A, p. 7.
29. Auckland Thermal No. 1 was first proposed in 1970 as four gas-fired 250 MW units with others to follow. In the following years various sites were considered: the Waitemata and Kaipara Harbours and the Firth of Thames. In 1972 this station was deleted from the programme and replaced by the Huntly station, but the following year, with agreement reached on Maui gas, it was reinstated nominally as four 350 MW units. After strong local opposition to the Te Atatu site in 1973 attention shifted to the south shore of the Manukau Harbour. Auckland Thermal No. 2 was first proposed in 1974 as a gas-fired station with three 350 MW units likely to be sited in South Auckland. After preliminary Environmental Impact Reports were prepared for six sites in 1974, Waiau Pa on the southern shore of the Manukau Harbour was selected in 1976 for the No. 1 station and an Environmental Impact Report was prepared. After legal battles before the Planning Tribunal, and with the increase in demand for electricity declining, in 1977 the stations were first deferred and then dropped entirely from the programme.
30. *Who's Who in New Zealand*, 1978. *Notable New Zealanders: the Pictorial Who's Who*, 1979. *Evening Post*, 26 September 1972. *NZ Engineering*, 15 November 1979. Personal communication from P. W. Blakeley.
31. Personal communication from K. D. McCool.

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2. Personal communication from Harold Jenks, Fellow of NZ Institute of Surveyors.
3. W. A. Bloodworth, 'Lake Taupo control', NZ Institution of Engineers, *Proceedings*, vol. 29, 1943. G. L. Nanson, 'Lake Taupo control: construction', *NZ Engineering*, 10 January 1947.
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6. *NZ Herald*, 7 April 1947.
7. Items on 'Ten-year plan', *NZ Electrical Journal*, 25 October and 25 November 1943.
8. For Mangakino, see C. Hasman, *Mangakino in Perspective, 1945–1965: the Story of a Hydro Town*, Turangi: Tongariro Welfare Association, 1965. Hasman, 'The development of hydro-electric resources'. *Mangakino Chronicle*, 7 November 1952, special commemorative supplement.
9. *AJHR*, 1946, D-4, p. 3.
10. Hasman, 'The development of hydro-electric resources', p. 26.
11. Ibid., p. 32.
12. For Maraetai I and II, see *Maraetai power station*, State Hydro-electric Department, August 1952. P. W. Blakeley, *Maraetai, New Zealand: Largest Station in North Island's Waikato River Chain*, State Hydro-electric Department, *c.* 1953. 'Maraetai II power station', Electricity Department, October 1966. 'Maraetai II', 'Mistake was to start Maraetai II at all', 'Maraetai II hydro-electric scheme', undated papers in Electricity Corporation Historical Collection.
13. *Mangakino Chronicle*, 7 November 1952, supplement, p. 1.
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15. *Atiamuri*, NZ Electricity Department, 1971. *Water Power*, October 1959.
16. *Waipapa*, Electricity Department, 1974.
17. *Ohakuri*, Electricity Department, n.d.
18. *AJHR*, 1904, D-7, p. 10.
19. *AJHR*, 1954, D-1, p. 21.

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5. The proposed dams on the Kawarau River were abandoned in 1985 for environmental reasons. The Luggate and Queensberry dam proposals for the upper Clutha entered the power plan in 1980 and remained there until such documents ceased to be produced in 1986. An Environmental Report for these two proposed dams was produced in 1982, and in 1985 Luggate was granted water rights and other statutory clearances. In 1987 the Electricity Corporation deferred the proposals on commercial grounds, but investigations and development work continued for a time. The lower Clutha, below Roxburgh, has also been considered as part of the river's overall development, and it appeared in the power plan in 1982 and remained there until 1986. A report on the potential of this section of the river published in 1986 outlined four possible schemes involving a 'cascade' of between two and four dams, and compared them on the basis of cost and impact on land, communities and the environment.

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3. *Evening Post*, 20 September 1986, advertisement.
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13. *Connections*, no. 19, December 1993.
14. *NZ Herald*, 4 February 1993. *National Business Review*, 5 February 1993.
15. This was undertaken by the MRL Research Group from late 1992 onwards.
16. John Boshier, General Manager, Strategic Development, pers. comm. Boston Consulting Group, *Report to Steering Committee* [ECNZ], 3 August 1994. Boston Consulting Group, *Capability 2000: Developing Capabilities for a World Class Future* [ECNZ], January 1995.
17. ECNZ, *Environmental Report*, 1998, p. 6.
18. *Dominion*, 5 December 1990, editorial.
19. *Manawatu Evening Standard*, 6 June 1992.
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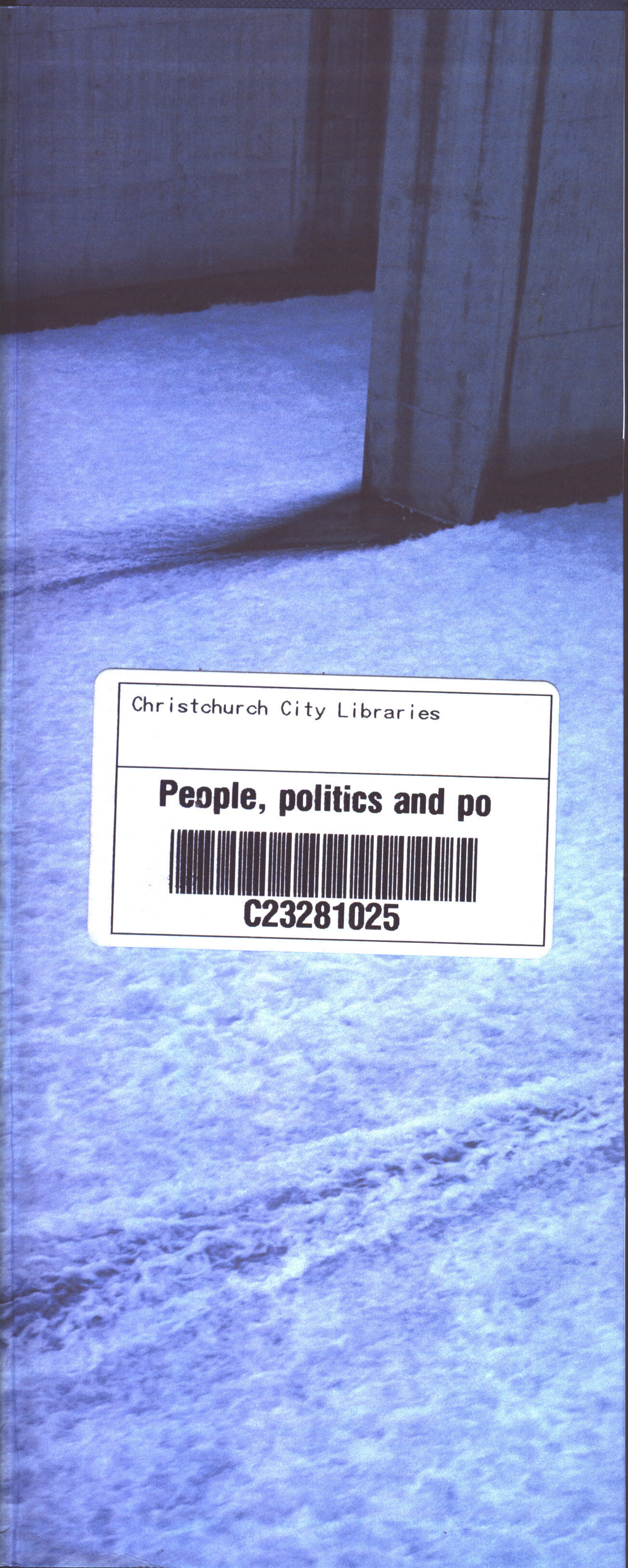

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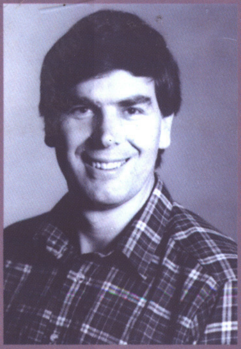

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